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ENGINEERING REPORT: TETHERED FLOAT BREAKWATER NEAR-SHORE OCEAN --ETC(U)
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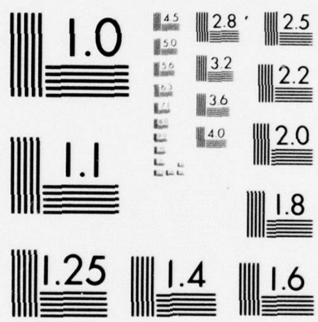

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Technical Report 378

ENGINEERING REPORT: TETHERED FLOAT BREAKWATER NEAR-SHORE OCEAN MODEL.

J.D. Clinkenbeard

September 1978

Interim Report. October 1976 – August 1978

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ERRATUM

Please replace page 3 with the enclosed page 3/4 in Naval Ocean Systems Center Technical Report 391, Poseidon Communications Improvement Program Technical Evaluation Test Plan for Modular Interface Multiplexing and Switching Unit and Submarine Advanced Keyboard-Printer, by R. Leffler dated 15 March 1979.

1. INTRODUCTION

This document presents the plans for a series of environmental tests on two interrelated units: a modular interface multiplexing and switching unit (MIMS) and a submarine advanced keyboard-printer (SAKP). The MIMS unit is a preproduction unit, which upon acceptance will be installed as part of the POSEIDON Communications Improvement Program (PCIP). The SAKP is an off the shelf militarized unit that has been tested previously in accordance with requirements of the British Ministry of Defence Technical Specification TS-1527. Parts of this specification were compounded by inputs from national standards of the United Kingdom, United States of America, Canada and Australia. Subsequent to those tests some functional and physical modifications were made to the printer to permit its use in PCIP.

Adequate specifications for POSEIDON equipment were not available, therefore the requirements of MIL-E-16400, supplemented by those of the TRIDENT class submarine, will be used in the environmental testing of the MIMS and SAKP.

Any revision to these procedures will be reflected in subsequent documents.

1.1 PURPOSE

These tests are intended to verify that the MIMS and SAKP meet their respective design parameters and that their exposure to the environmental requirements of the TRIDENT class submarines[1,2] will not damage or degrade their operation.

1.2 SCOPE

1.2.1 General

Testing will consist of a series of electronic measurements and unit operational tests (for gathering reference data) and environmental tests selected from Table V of Reference 3. Table 1 of this report lists the environmental tests to be performed, the requirement reference which the unit under test must meet and the reference describing the test procedure.

1. Specifications for Building Submarines SSBN TRIDENT Class, Naval Ship Systems Command, NAVSHIPS 0902-027-7010, Volumes 1, 2 and 3, 22 May 1973.
2. Specification for Integrated Radio Room for TRIDENT Submarine, Naval Electronic Systems Command, 8556800F, 5 November 1977.
3. Electronic, Interior Communication and Navigation Equipment, Specification, Naval Ship and Shore: General Specification for, MIL-E-16400G, 24 December 1974 (with Amendment 1 dated 1 December 1976).

Table 1. References to test requirements and procedures.

Test	Unit Under Test		Requirements Document, Paragraph Number	Test Procedure Document, Paragraph Number	Comments
	MIMS	SAKP			
Surface inspection	X	X	Spec. 8556800F, 3.3.2, 3.3.4	MIL-E-16400G, 4.8.1	
Low temperature	X	X	Spec. 8556800F, 3.2.6.1	MIL-E-16400G, 4.8.3.2	Range 4 equipment
High temperature	X	X	Spec. 8556800F, 3.2.6.1	MIL-E-16400G, 4.8.3.3	
Humidity	X	X	Spec. 8556800E, 3.2.6.2	MIL-E-16400G, 4.8.3.4	
Vibration	X		Spec. 8556800F, 3.2.6.4	MIL-STD-167B, Type 1	Note 1
Shock	X	X	Spec. 8556800F, 3.2.6.3	MIL-E-16400G, 4.8.3.14	
Magnetic materials	X	X	MIL-E-16400G, 3.7.6.1	MIL-E-16400G, 4.8.4.4	
Enclosure	X	X	NAVSHIPS 0902-027-7010, Section 9670-0-b	MIL-E-16400G, 4.8.4.3	
Electrical power	X	X	Spec. 8556806C, 3.1.2.3	MIL-E-16400G, 4.8.5	
Airborne noise	X	X	NAVSHIPS 0902-027-7010, Section 9400-2-b	MIL-STD-740-1	Note 2
Structureborne noise	X	X	Spec. 8556800F, 3.2.6.8	MIL-STD-740B, 5.4	
Inclination	X	X	MIL-E-16400G, 3.3.5.15	MIL-E-16400G, 4.8.3.16.2	
Magnetic field	X	X	Spec. 8556800F, 3.2.6.5	MIL-E-16400G, 4.8.3.17	
Salt fog	X		MIL-E-16400G, 3.3.5.4	MIL-E-16400G, 4.8.3.5	
EMI	X	X	Spec. 8556800F, 3.3.3	MIL-STD-462	
Reliability	X	X			Note 3

Notes: 1. Vibration requirement modified by Section 9400-2-c of NAVSHIPS 0902-027-7010
2. MIL-STD-740-1 is presently in the review cycle and has not been approved.
3. Per NAVELEX Code 470 verbal direction.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the efforts at Naval Ocean Systems Center to design, fabricate and evaluate the Tethered Float Breakwater (TFB) Near-Shore Ocean Model. It provides all basic engineering information from functional concept to on-site emplacement of a full-scale model. Preliminary experiments by Scripps Institution of Oceanography established that cylindrical tethered floats, in a particular breakwater geometry, would provide an optimum wave-height reduction of up to 50 percent for a shallow-water, near-shore application. Fabrication proceeded on two three-component modules including floats, tethers and ballast assembly. This was followed by interim tests and evaluation of ballasting, surfacing and towing characteristics. Finally, the two TFB modules were towed to a Con't

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near-shore test site and evaluated through three phases: initial installation, realignment at 90 degrees to shore and transfer to a new near-shore site. This report concludes with basic engineering design recommendations, while a performance evaluation continues and is not provided here.

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Continued)

TABLES

INTRODUCTION

This report describes the design, fabrication and installation of the Tethered Float Breakwater Near-Shore Ocean Model, henceforth referred to as the TFB Ocean Model.

NEAR-SHORE TFB CONCEPT

The Near-Shore Tethered Float Breakwater (TFB) is constructed from a large number of buoyant floats with a characteristic dimension approximating the wave height. They are independently tethered below the surface to a bottom resting ballast system. The floats move in opposition to the incident wave field, responding like inverted pendulums. As the wave front passes through successive rows of floats, the drag produced by their oscillation removes energy from the waves, reducing the wave height. By selecting the number of rows installed and tuning the natural frequency of the float and tether system, the incident waves at the installation site can be reduced to a desired height. The breakwater is assembled from the required number of standard modules which are transported or towed to the deployment site. Reference 1 is a detailed discussion of the operational theory of a TFB system.

Figure 1 illustrates one module of the final configuration of the Tethered Float Breakwater Ocean Model. The cylindrical floats (128 units) constructed from used automobile tires are attached to the ballast with synthetic tethers. The bottom-resting framework (30 ft × 60 ft) is fabricated from scrap rail and four steel ballast tanks which enable the assembly to be refloated and transported to a new location.

A series of one-half scale model experiments conducted by Scripps Institution of Oceanography resulted in performance predictions for the Imperial Beach Breakwater (Ref. 2). In Table 1, the predicted height transmission factor is shown for three tide stages and for three installation depths.

TABLE 1. BREAKWATER PERFORMANCE PREDICTIONS
(for significant wave height of seven feet; wave period of 8 seconds)

	Height Transmission Factor		
Depth at MLLW (ft)	Low Tide (-2 feet)	Mid-water	High Tide (+6 feet)
21	0.81	0.87	0.91
23	0.77	0.85	0.89
25	0.72	0.81	0.87

These values convert to wave reductions of 9 percent to 28 percent.

1. Tethered Float Breakwaters, Conference on Floating Breakwaters, Newport, RI., R. J. Seymour and J. D. Isaacs, March 1974.

2. Design of the Bottom-Resting TFB for the Silver Strand Experiment, TFB Ocean Experiment; Technical Note 11, David Castel, Oct. 1977.

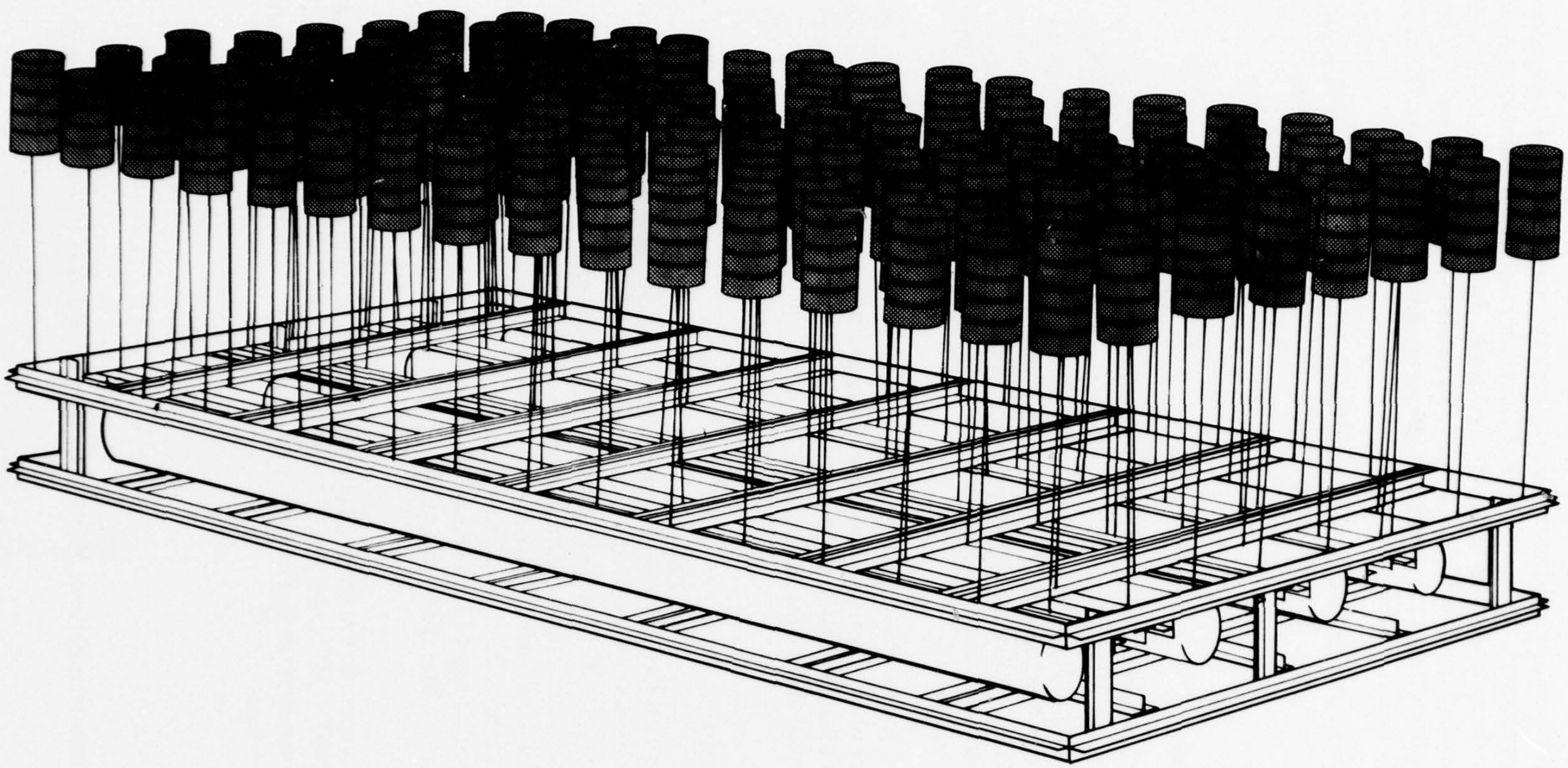

Figure 1. Tethered Float Breakwater Ocean Model (one module).

These performance predictions are based upon the particular breakwater geometry selected for this experiment, that is, 16 rows of floats. Increasing the number of rows of floats will improve the performance under all conditions. In general, wave height reductions of up to 50% or so (energy reductions of 75%) result in a reasonable number of rows. Much greater reductions than these require progressively greater additions to the numbers of rows and rapidly become unfeasible.

The Tethered Float Breakwater is a portable system that can be used in applications such as dredging, pipe laying, drilling, cargo transfer and amphibious assaults to attenuate local wave height.

TEST OBJECTIVES

The primary purpose of the Tethered Float Breakwater Ocean Experiment is hardware performance verification. A complete prototype system (including ballast, tethers and floats) will be designed, constructed and installed at a pre-selected site. Its ability to survive in the ocean environment will be evaluated over a period of 12 to 18 months. Areas of interest will include corrosion resistance, fouling, abrasion, burial and scouring. Relocation experiments will be conducted to demonstrate the requirements for deballasting, breakout and short haul towing.

A secondary goal of the Ocean Experiment is performance evaluation. The direction and spectral content of the local incident wave climate will be monitored. Wave attenuation will be compared with analytical predictions of performance. The breakwater's effect on sediment transport will also be investigated.

INSTALLATION SITE

The original TFB Ocean Model installation site (32°35′15″N, 117°08′10″W) is located approximately 400 yards off shore from Imperial Beach, CA., 0.5N mi north of the Municipal Pier (Figure 2). This site was selected because the area is subjected to open ocean waves throughout the year, ranging from northwest in the winter to south in summer. The ocean bottom is firm, level sand. Water depth is 25 feet at mean lower low water. The significant wave height ranges from 1 to 5 feet throughout the year with an average of 3 feet (Ref. 3); the wave period is 6 to 10 seconds. This area is also in proximity to an existing test installation, where tethers and tether terminations are being evaluated over a long term period.

Later in the program, the Ocean Model was moved to its present test site, 2,400 yards to the north (32°36′25″N, 117°08′11″W). The bottom conditions are identical to those above. Water depth is 20 feet at mean lower low water. The modules are located 250 yards from the beach.

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3. California Coastal Engineering Network, Monthly Summary Reports, May 1976 through December 1977.

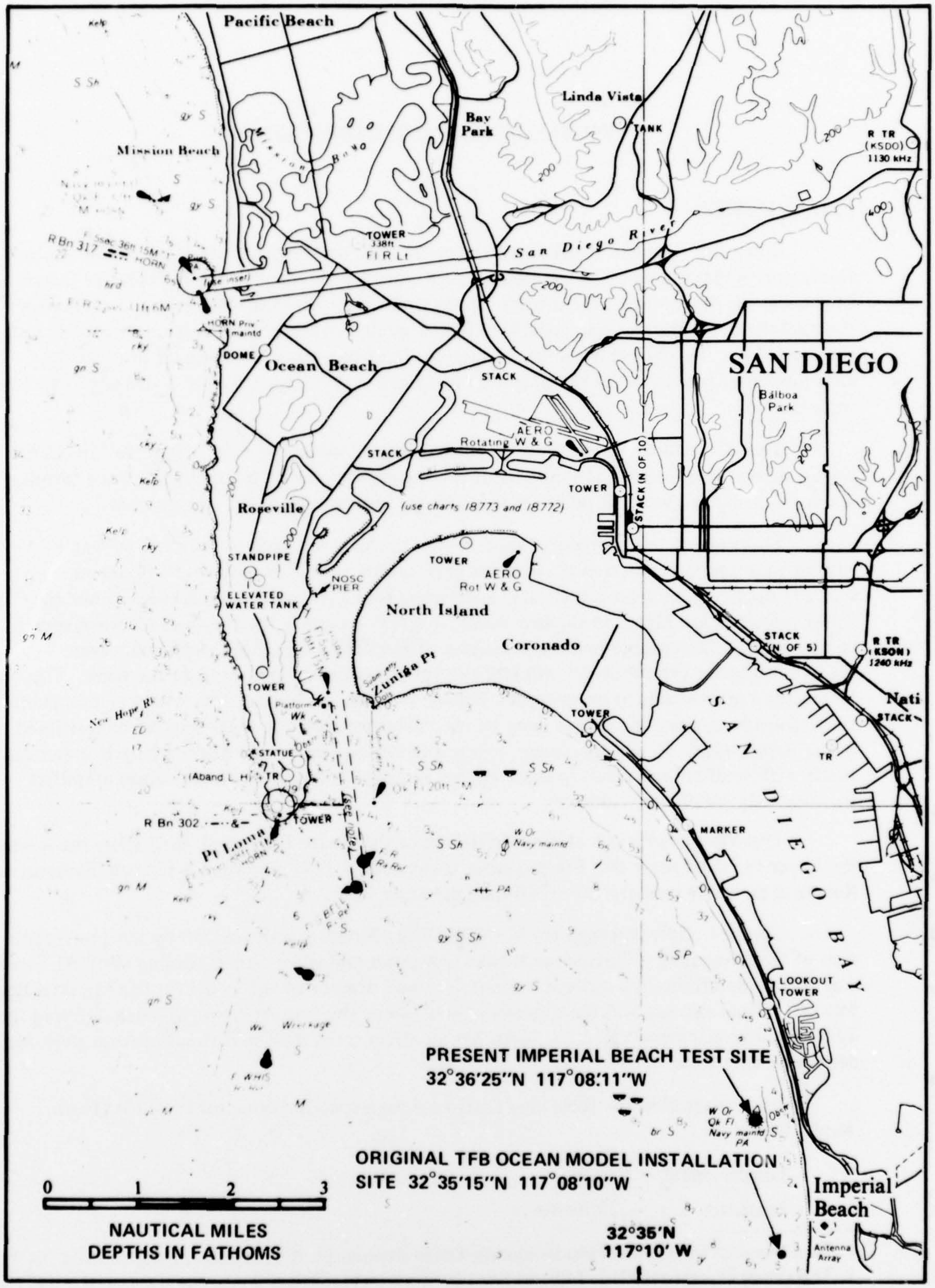

Figure 2. Tethered Float Breakwater Ocean Model installation site.

INITIAL DESIGN AND FABRICATION

FLOAT DESIGN

Since the Tethered Float Breakwater operates on the principle of energy extraction, floats were a major area of investigation. As a wave passes through the breakwater the energy of the wave is dissipated as the motion of the floats overcomes the fluid drag associated with their oscillatory motion. This reduction in energy decreases the height of the wave behind the float field. To achieve optimum reduction, the floats must be designed to meet the environmental conditions at the proposed installation site, primarily the water depth and wave period.

The water depth determines the motion of the water particles of a wave. In deep water, such as open ocean, the motion of the water particles is circular as the wave travels, whereas, in shallow water it becomes increasingly elliptical until the wave breaks.

These elongated horizontal wave orbital motions are used in the shallow water system to improve performance. For this application, modified cylindrical floats are selected because they have a high drag coefficient and also a large added mass. Since the water velocities are higher in shallow water, it is not necessary for the float to move very fast to produce acceptable relative velocities. Therefore a high drag coefficient, even though it inhibits float motion, will still extract considerable energy from the wave. The large added mass assists in lowering the natural frequency of oscillation which is important to performance, since the tether must be much shorter than the ideal because of restricted water depths (Ref. 5). In deepwater, where the tethers can be any desired length, spherical floats with smaller drag result in more energy removal because the float motion amplifies the relatively small water motion.

The wave height also affects the design of the float. In general, the higher the waves, the larger the float must be. For example, a bay model TFB may have a 12-inch diameter float and an ocean model a 36- to 60-inch diameter float.

Conceptual float design for the TFB Ocean Model was developed by Scripps Institution of Oceanography. Through extensive computer and wave tank modeling (Ref. 4), Scripps was able to determine the optimum shape, size and density of the floats for the Imperial Beach test site. Float spacing and the number of rows were also important variables in defining the TFB in functional terms (Ref. 6). Each has an effect on system performance for a given incident wave spectrum.

This resulted in the following baseline design specifications for the TFB Ocean Model float:

Displacement – 850 lb

Diameter – 25 inches

4. Final Report, The Tethered Float Breakwater Ocean Experiment, R. J. Seymour, 1 Oct 76 to 31 Oct 77.
5. TFB Ocean Experiment TN 7, Tethered Float Breakwaters for Shallow Water, David Castel, May 1977.
6. Performance of Tethered Float Breakwaters in Deep Water Ocean Waves, Richard J. Seymour, Nov 1975.

Length – 50 inches

Float Weight – 475 lbs. (based on a dry weight to in-water displacement ratio of 0.56)

The center of gravity of the cylindrical float must coincide with its center of buoyancy to insure stability.

In addition to the specifications resulting from the computer modeling study, the design criteria of cost, corrosion resistance, resistance to marine organisms, and ecological compatibility had to be met. In an informal market survey of commercially produced floats, it was revealed that currently there are no floats meeting the design criteria of the open-ocean test module. Because of the size, shape, and composite density requirements, the floats were considered development items by the manufacturers contacted. This led NOSC to investigate the problem, resulting in a fabrication method for a float with the desired characteristics.

This method, using scrap automobile tires, concrete, and polyurethene foam, provides an inexpensive float that can be built to any preselected buoyancy. See Figure 3.

Tires (five or six per float depending on size) provide a protective mold for the foam and concrete. Steel reinforcing rod was used as a longitudinal strength member, and also formed the bail (tether attachment point) at the lower end of the float. The bail was covered with PVC suction hose to prevent abrasion of the tethers. Appendix A is the initial calculation of material weights and volumes based on a foam density of 2 lbs/ft^3.

Two prototype floats were constructed according to the specifications given in Figure 3, and installed at a water depth of approximately 20 feet off Imperial Beach. Regular inspections over a period of several months indicated that the floats were losing buoyancy. This resulted from compression of the polyurethane foam. Further investigation in the laboratory indicated that the compressive strength of the foam being used was not adequate in the radial direction (direction perpendicular to rise).

Reichhold Chemicals, Inc., a large manufacturer of foam products, recommended a denser composition material (2.8 lbs/ft^3 nominal) that was better suited to the ocean environment. Laboratory analysis (Appendix B) conducted on a sample core of foam (also tested at depth) showed that the compressive strength was indeed superior to the previous polyurethane. Appendix C is a revised material calculation, based on a foam density of 2.8 lbs/ft^3 and the use of six tires per float.

Popoff Foam, Inc., San Marcos, CA was awarded a contract to fabricate 256 floats for the TFB Ocean Model. A primary concern was keeping the overall weight of the floats uniform. Individual tires were weighed and grouped in sets of five or six to obtain the prescribed height of 50 inches (Figure 4). Preformed reinforcing rod (rebar) with PVC hose around the bail was embedded in concrete poured into a tire that would become the top of the float (Figure 5). Subsequent tires were stacked over the "rebar" and the core filled with polyurethane foam. Figures 6, 7 and 8 illustrate this technique. (The main body of these tires was foamed in a separate operation). The last tire was then capped with concrete, and the final weight of the float adjusted (Figure 9). A completed Ocean Model float is shown in Figure 10.

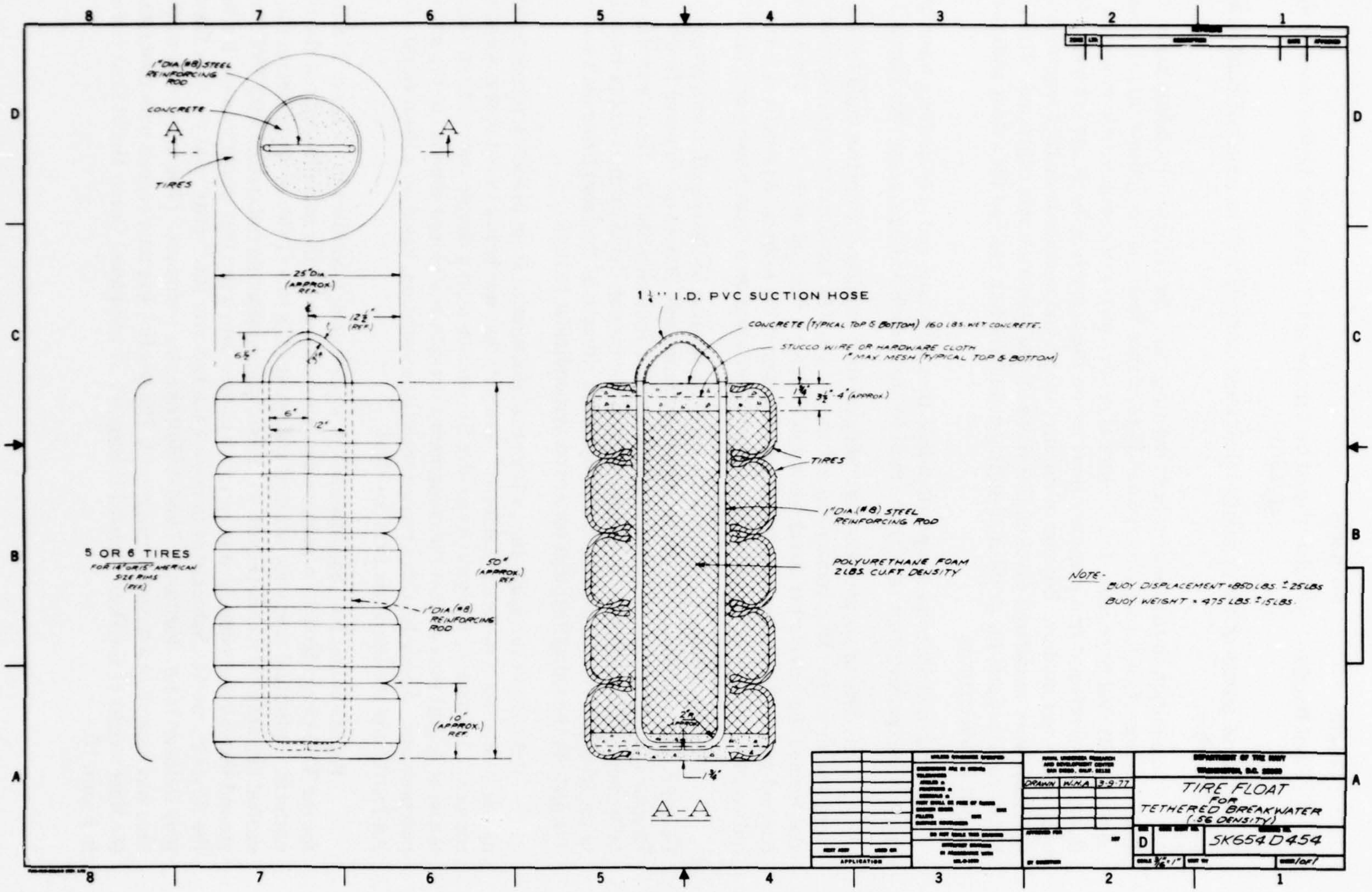

Figure 3. Tire float for tethered float breakwater (0.56 density).

Figure 4. Sorting tires for float fabrication.

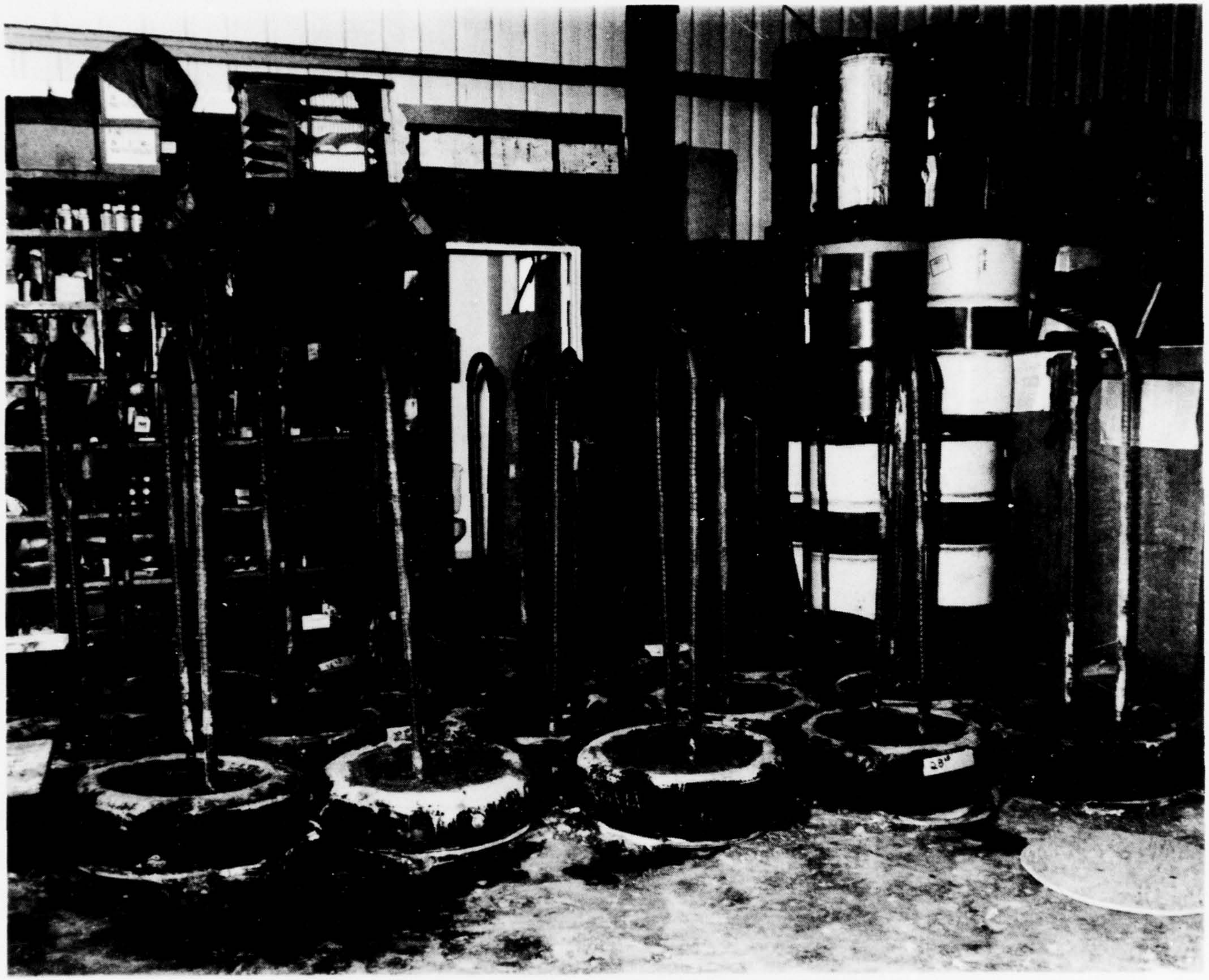

Figure 5. Concrete foundation with preformed reinforcing rod.

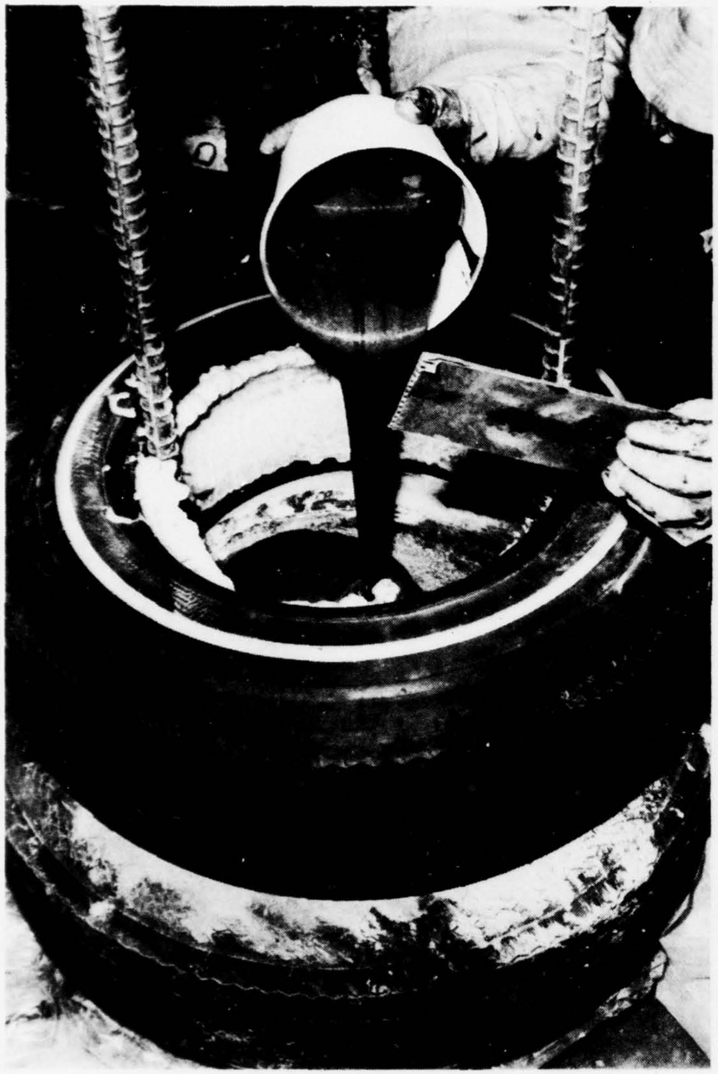

Figure 6. Foaming the core of the float.

Figure 7. Foam core curing.

Figure 8. Final pour of polyurethane foam.

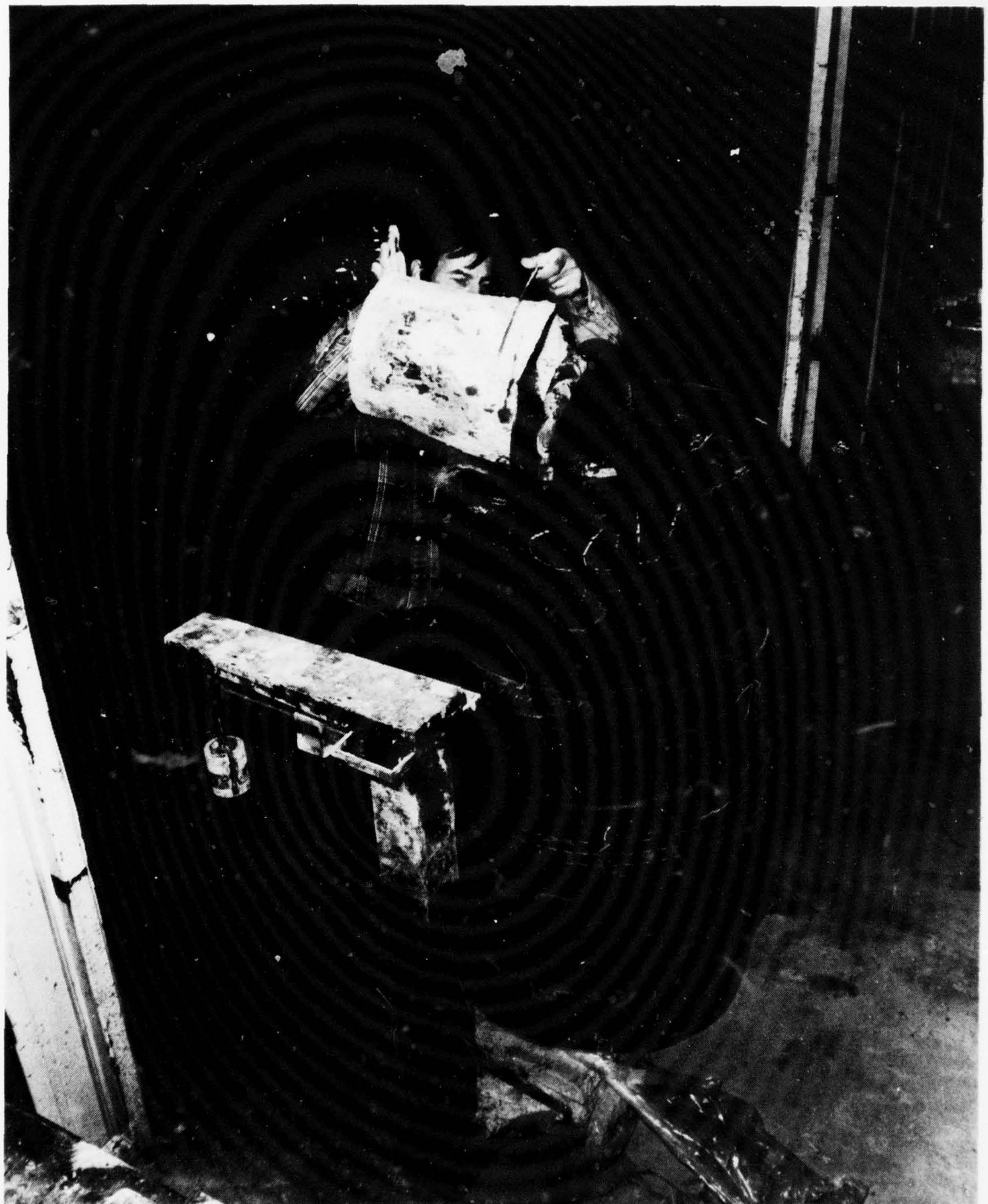

Figure 9. Capping float with concrete to adjust weight.

Figure 10. Tethered Float Breakwater Ocean Model tire float.

TETHER DESIGN

The development and testing of tethers and tether terminations for the TFB Ocean Model was a cooperative effort between Lane Instrument Company, El Cajon, CA and NOSC personnel. Basic design theory, formulated for wire rope terminations (Appendix D), was applied to the Ocean Model components. A test and evaluation of tether assemblies was performed both in the laboratory and in situ at an Imperial Beach test site.

Baseline design specifications required a tether assembly to withstand five years (15 to 20 $\times$ 10^6 cycles) in an ocean environment with wave periods of six to ten seconds. Previous experiments conducted with TFB Bay Model hardware indicated that bending stresses at the base of the tether should be minimized to prolong its life expectancy (Ref. 7).

The bending radius of the tether and the point at which bending occurs can be controlled by using a flexible terminator or boot. The boot design should be such that a minimum bending radius of the tether is eight inches under a cyclic load of 300-800 pounds (determined to be the dynamic loading range for the Ocean Model floats) and a tether excursion of ±17½ degrees in all planes through the vertical axis of the boot.

The tether must have a tensile strength of five times the buoyancy of its associated float (maximum dynamic loading of 800 pounds). Long-term creep may not exceed ten percent of the tether length. Large variations in the lengths of tethers would significantly reduce the performance level of the system, by moving the spectrum of maximum wave attenuation to other than that for which the TFB was designed. Tethers must also withstand biological fouling, silt and sand, corrosion and temperature extremes. Line torque under a loading of 300 to 800 lb. should not exceed one degree to prevent internal abrasion.

Based on a water depth of 25 feet at mean lower low water, and a tether flexure height of four feet above the bottom, the tether length at 375 pounds axial tensile load (nominal float buoyancy for Ocean Model) shall be 132 inches. This length will suspend the top of the floats six feet below the surface at mean lower low water.

The above requirements were met by the tether assembly shown in Figures 11 and 12. Single braided polyester fiber line (Samson VLS) was used as a tether material. A six inch soft eye was spliced into one end for easy attachment to a float. The terminator was molded from polyurethane with a hardness of 55 Shore D and 16 second creep modulus of 2,800 PSI at the maximum deflection angle. An impregnated eye protruded from the base of the boot. Figure 13 shows the method of attachment. A steel pin passing through the lower eye was used to secure the tether assembly to the ballast frame.

Prototype tether assemblies, fabricated by Lany Instrument Co., for the TFB Ocean Model were mechanically tested in a controlled environment prior to manufacturing the 256 production units. Specimens were mounted in a tether test machine (Figure 14) in the manner similar to the final design specifications (figs 13, 17) for the TFB. The polyurethane boot was inserted in a short piece of steel tubing attached to a mounting plate? a steel pin passing through the tubing and the impregnated eye at the base of the boot was used to restrain the test sample. Because of the severity of the conditions in the machine (high rate of revolution and subsequent heat generation), a life of 3 X 10^6 cycles was considered equivalent to

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7. NUC TN 1670 – Engineering Report – San Diego Bay Tethered Float Breakwater; J. B. Berkley, Jr & N. F. Johnson, March 76.

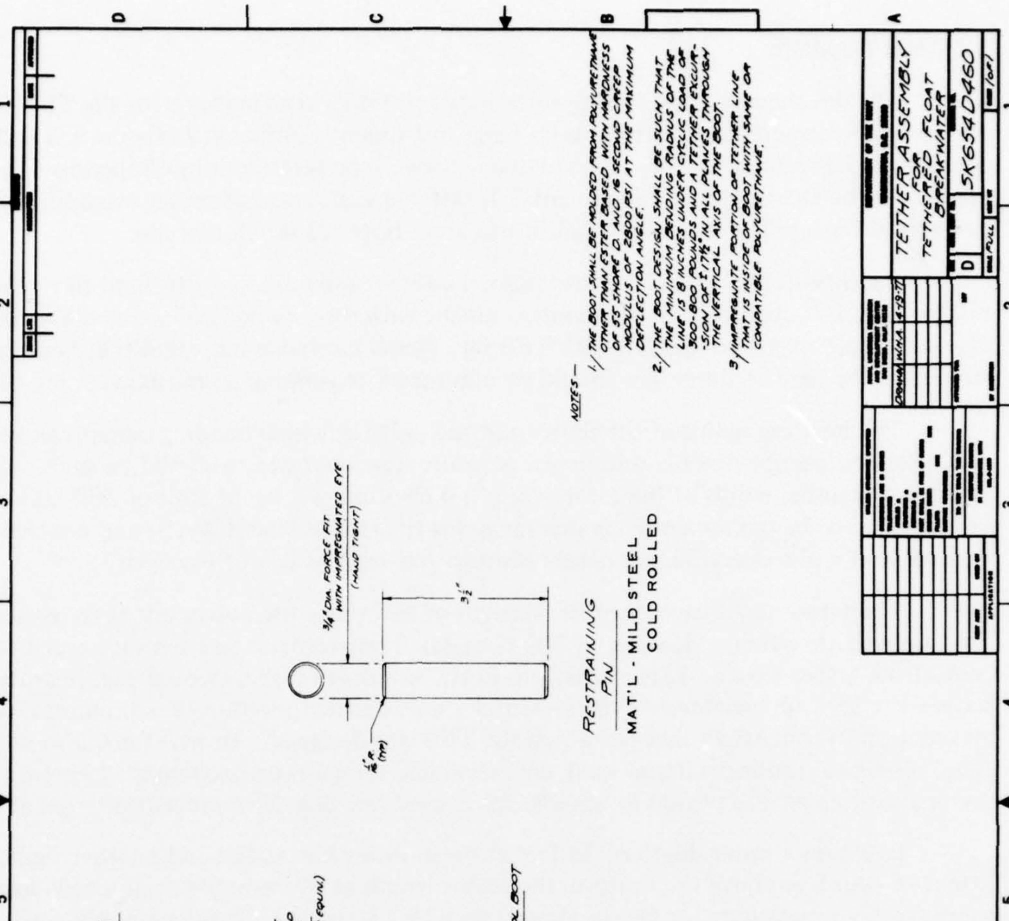

Figure 11. Tether assembly for Tethered Float Breakwater.

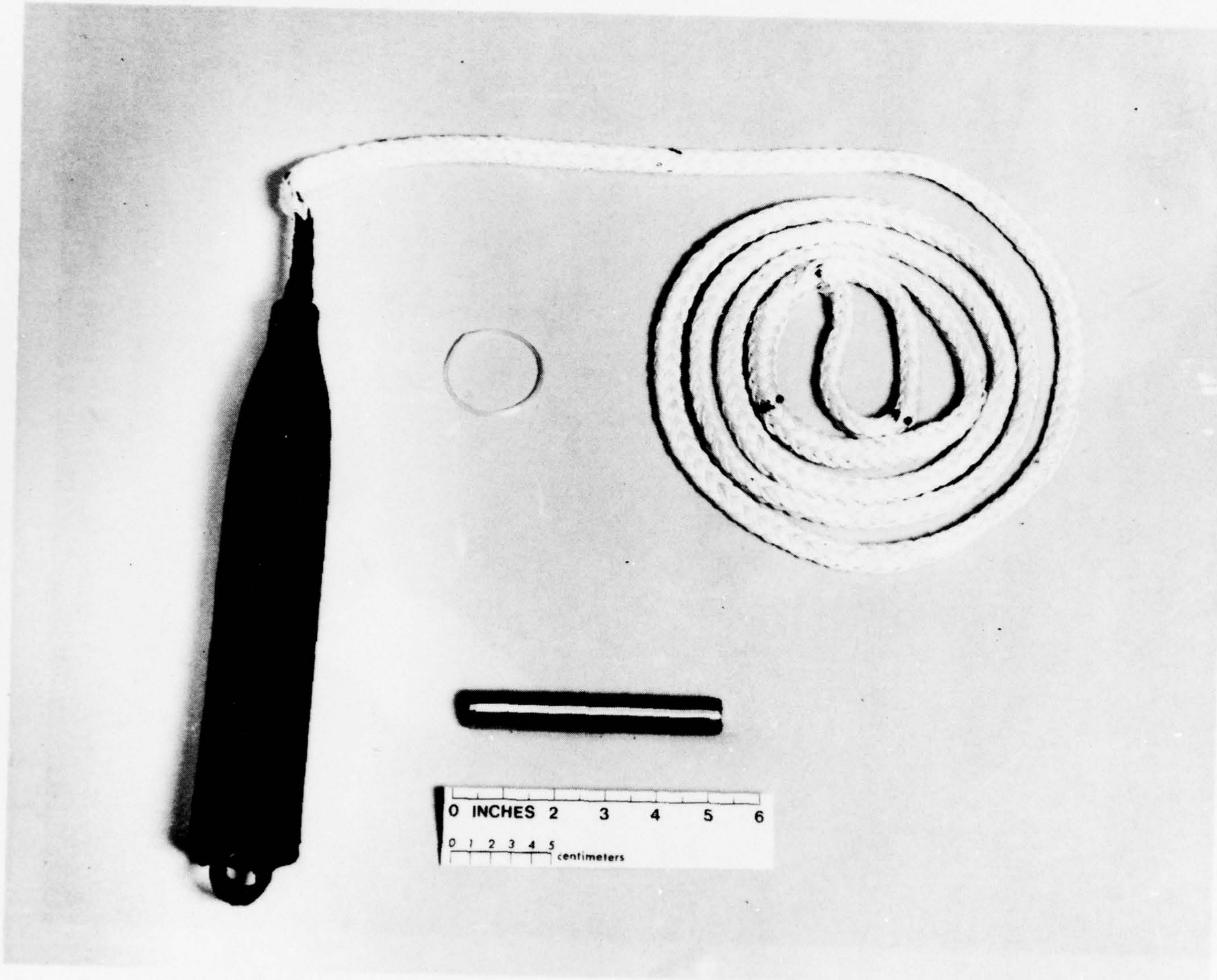

Figure 12. Tethered Float Breakwater Ocean Model tether assembly.

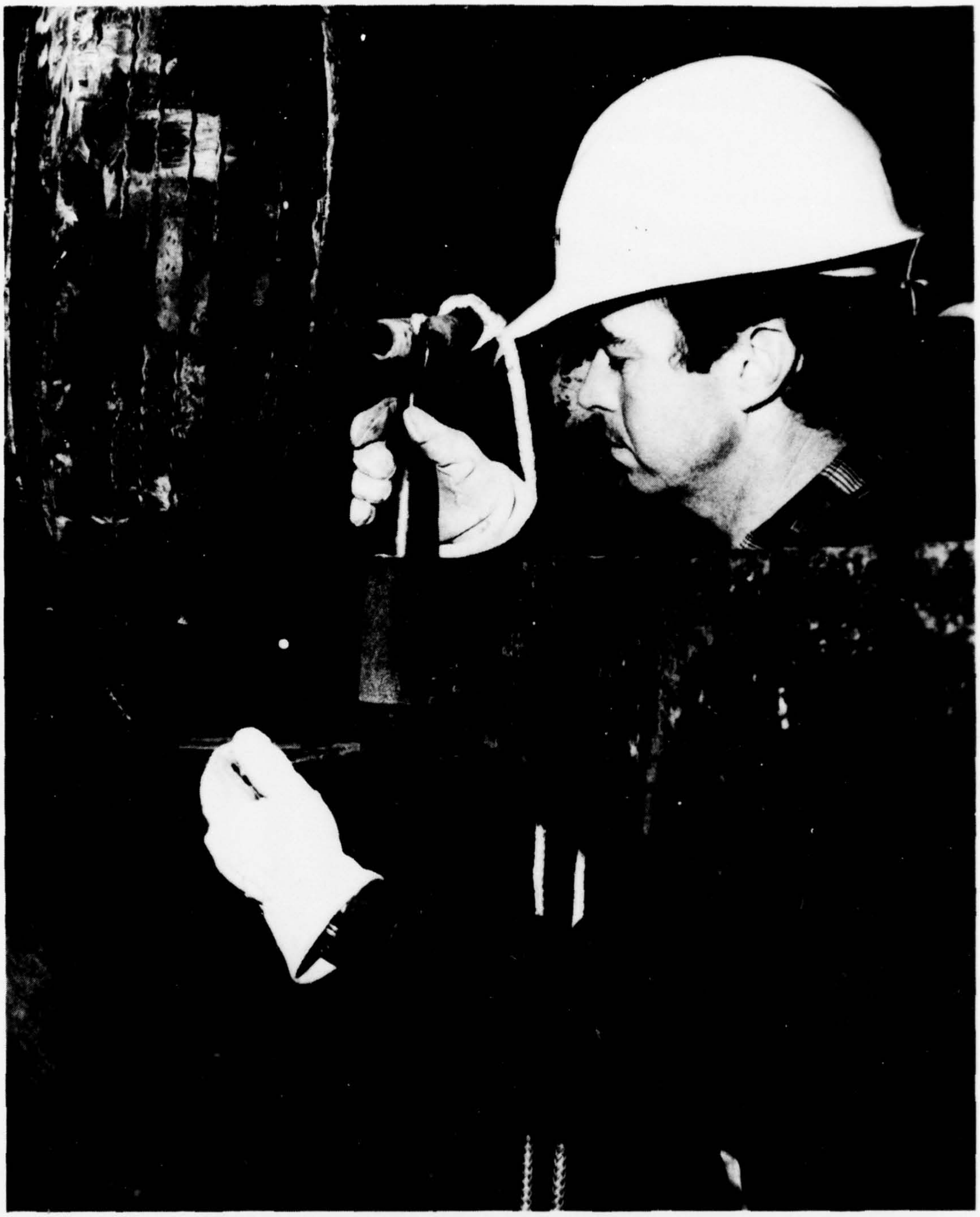

Figure 13. Attaching tether assembly to ballast.

Figure 14. Tether test machine.

the baseline requirement. Tethers were loaded to 800 pounds, and an angular deflection of ±15 degrees in all planes through the vertical axis of the boot was used. The lower portion of the tether was constantly immersed in sea water during testing. Test results are given in Table 2.

Two major problems were solved as a result of the testing program. It was discovered that the synthetic fiber being used as the tether material was coated with a sizing that prevented the polyurethane from curing properly. This had to be removed on all production units. It was also found that pre-tensioning the tether line during fabrication is essential to insure that all fibers are loaded equally. Test samples that were not pre-tensioned failed prematurely.

BALLAST DESIGN

The primary function of the ballast assembly of the TFB is threefold: 1) it provides an anchor to hold the floats at the desired depth, 2) it incorporates a variable deballasting system so that the breakwater can be raised and relocated, and 3) it provides convenient attachment points for the floats and a means for locating them in the proper spacing arrangement.

For the shallow water application off Imperial Beach, a bottom-resting system is most desirable (Ref. 4). A non-floating ballast configuration allows maximum tether length, and eliminates the need for near-horizontal mooring lines which create chafing problems.

The TFB module must be portable. This feature is advantageous for the temporary protection of work sites such as dredging, pipe laying, or drilling operations. To provide mobility, the ballast will incorporate a deballasting system to reduce its in-water weight. When it is desired to move the breakwater the complete assembly can be refloated, allowing it to be towed to a new site. The ballast frame would remain negatively buoyant in the transport mode to prevent component damage. The frame rises until the floats penetrate the surface sufficiently to achieve equilibrium.

For long distance transportability, at ship speeds of 20 knots, the overall size of each module should be restricted to the limits of standard commercial cargo transports (30 ft X 60 ft) such as a LASH ship.

The available buoyancy of the complete assembly must also be adequate enough to provide the necessary breakout forces from the sea floor. Reference 8 states that, for sandy bottoms, breakout will occur for a slightly buoyant object although a finite time period may be required. A large safety factor on total lift force was incorporated.

The in-water weight of the ballast must be sufficient to overcome the buoyancy of the floats and prevent any horizontal excursions in response to lateral float loads transmitted through the tethers.

Float attachment points of adequate strength must be provided on the framework with a center-to-center grid spacing of twice the float diameter (Ref. 1).

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8. NCEL TR R-755: Unaided Breakout of Partially Embedded Objects From Cohesive Seafloor Soils, Naval Civil Engineering Laboratory, Port Hueneme, CA., Feb 1972.

TABLE 2. OCEAN MODEL TETHER TESTS

Sample	Condition	Start	Stop	Total Time	No. cycles	Remarks
1	Pre-tensioned 500 RPM	0427/1412 29/1045	0428/1953 30/2341	66hr 37min	1,998,500	Connecting rod broke on test machine. Boot failed at top edge of pipe (no inside radius on pipe).
2	Pre-tensioned 508 RPM	0725/1510 27/0853	0726/1659 30/0858	97hr 54min	2,983,992	Drive belt slipped on machine. Tether elongated to maximum length permitted on machine. Boot cracked 2/3 through at top of pipe. Air pocket extended from eye up 8-10 inches. Impregnated eye rotated. Polymer vaporized due to heat build-up within boot (about 300° F).
3	Not pre-tensioned 508 RPM	0801/1130	0803/1336	50hr 06min	1,527,048	Boot cracked at top of pipe. Some signs of vaporized polymer in upper part. Cone shaped pocket in lower portion worn by line after boot separated. Line parted unevenly.
4	Not pre-tensioned 502 RPM	0822/1110 24/1410	0823/1323 25/1629	52hr 32min	1,582,304	Vibration switch cut out on test machine. Boot cracked at top of pipe ¾ through. Polymer vaporized within boot as above. Line failure pending. 2 inches of line pulled out of boot at top.
5	Pre-tensioned 302 RPM	0826/1120	0829/0154	62hr 34min	1,133,708	Polymer did not cure within boot. Boot walked up line and out of pipe. Outer part of eye splice broke at base of boot. No damage to boot. Sizing on line prevented resin from curing.
6	Pre-tensioned 240/245 RPM	0908/1027 1025/1420	0922/1225 1110/0750	715hr 28min	10,415,970	Drive pulley failure on machine. Boot cracked through at top of pipe. No evidence of line parting or air pocket in polymer.

Note: tether failure was defined as complete separation of line and/or boot. In samples 1, 2, 4, and 6 this did not occur; however, while inspecting the tethers during mechanical repair of the test machine, it was observed that failure was eminent.

The following design criteria for the TFB Ocean Model ballast sections were established.

- Bottom resting ballast in 25 feet of water.
- Deballasting capability.
- Maximum dimensions of 30 by 60 feet (based on size restrictions of current LASH-type cargo vessels).
- Provision for four foot center-to-center spacing of floats (based on a float diameter of two feet).
- Minimum in-water weight of 96,000 pounds (based on a two to one ratio of ballast weight to net buoyant force of the floats).
- Economical fabrication.
- Strength to withstand operational handling, towing and implantment.
- Minimum service life (with minor maintenance) of 18 months for the TFB Ocean Experiment.

A comprehensive tradeoff study was performed on several design configurations, materials, and fabrication techniques capable of meeting the design criteria. The feasibility and expense of using concrete and steel pipes of various sizes, steel rails, chain, concrete pilings, and combinations of these materials were investigated. A summary of this study is presented in Appendix E.

As a result of this study, a combination of 36 inch OD steel pipe and rail (119 pounds per yard) was selected because the cost, availability, and functional characteristics proved to be the most desirable. Figure 15 shows a completed Ocean Model (single module) ballast section.

The ballast assembly required the bulk of the system design effort. Initial calculations were performed to determine the required lengths of pipe and rail. The original float buoyancy of 364.67 lb was used; it was assumed that the tethers would have a tensile load of 40 lb. each with the tanks completely deballasted. Appendix F lists the values obtained (i.e. 201 feet of pipe; 2,162 feet of rail). These were used to outline the general ballast configuration. Pressure limitations of the 36 inch OD and 0.281 inch wall pipe are given in Appendix G.

Detailed structural drawings are reproduced in Figures 16, 17, 18, 19, and 20. Steel rail weighing 119 lb/yd (dimensions are given in Appendix H) was used to form symmetrical top and bottom grids which protect the four longitudinal ballast tanks. Overall dimensions of the frame are 29 feet 4-3/8 inches × 60 feet × 4 feet 2 inches (Figure 16). Structural members were spaced at nominal distances of 4 feet on the upper grid to accommodate tether sockets used for float attachment. The sockets are WDOM steel tubing 2.125 inch ID with 0.188 inch wall; 4 foot center-to-center spacing resulted in 128 floats per ballast. The inside rim of each socket was rounded to prevent damage to the boot during its oscillations. Double rails were used laterally to increase the section modulus through a longitudinal plane. The ballast tanks provide the majority of the section modulus in the lateral plane. See Figure 17.

The lower grid was designed to rest evenly on the sea floor, and protect the underside of the tanks (Figure 18). Four 55-foot-long cylindrical steel pipes (36 inch OD × 0.281 inch

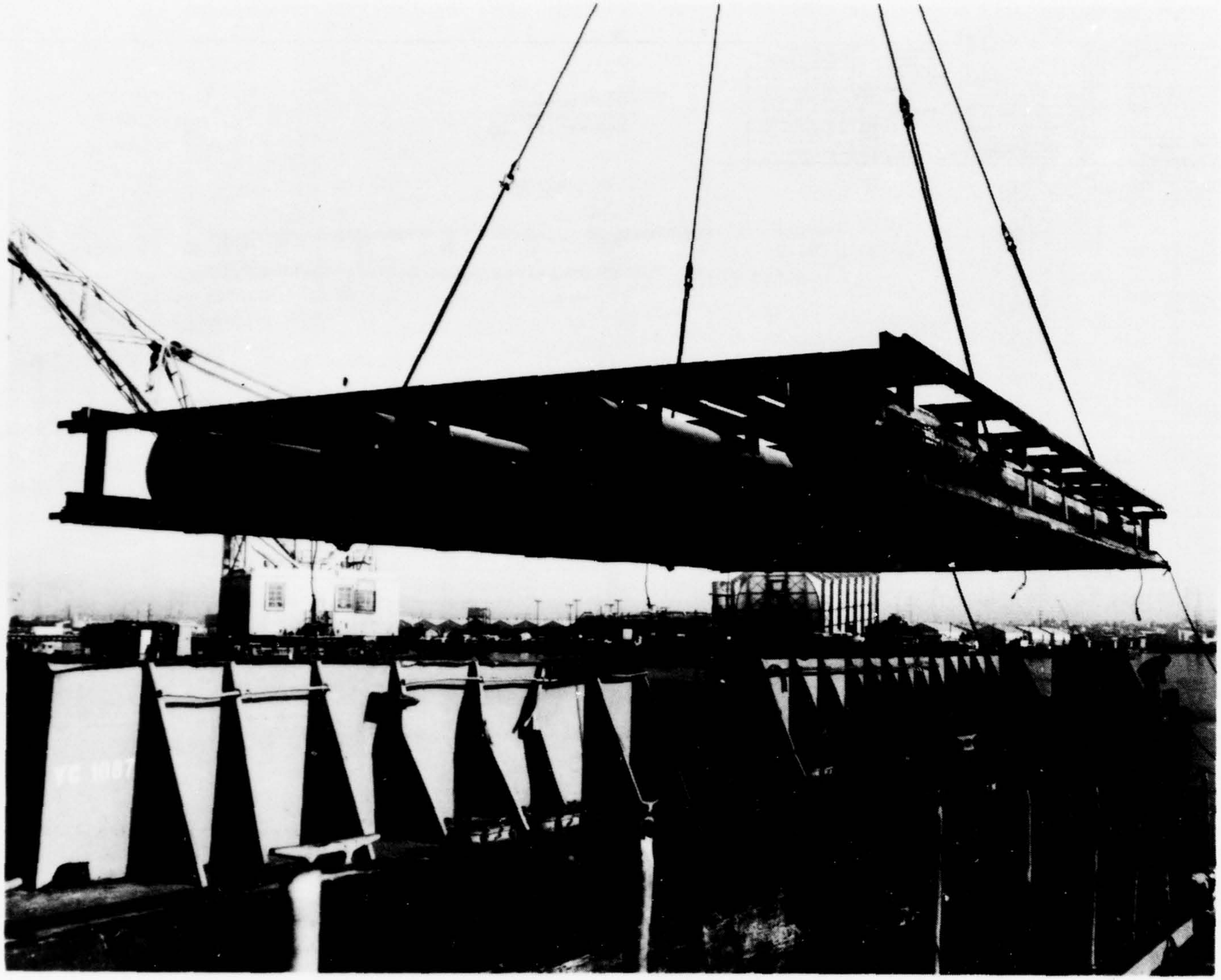

Figure 15. Tethered Float Breakwater Ocean Model ballast assembly.

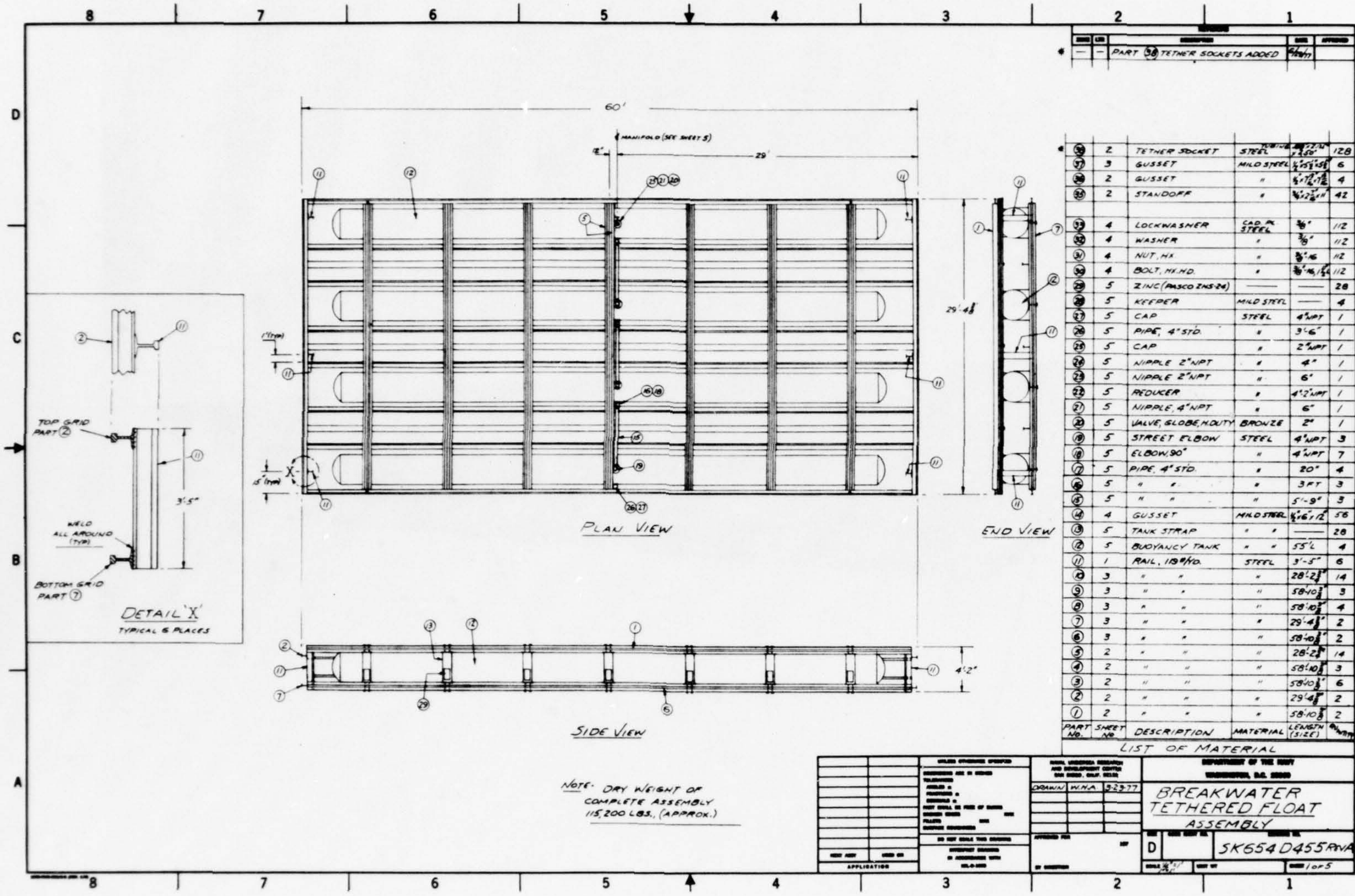

Figure 16. Tethered Float Breakwater ballast assembly.

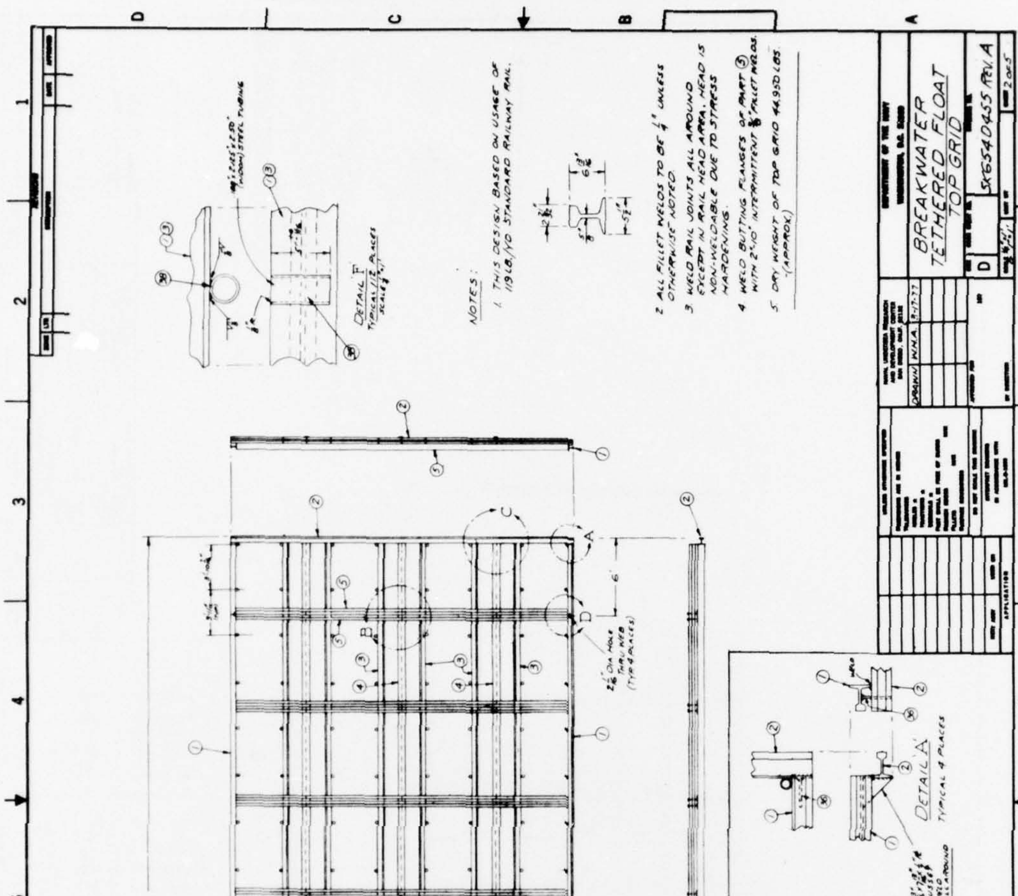

Figure 17. Tethered Float Breakwater ballast, top grid.

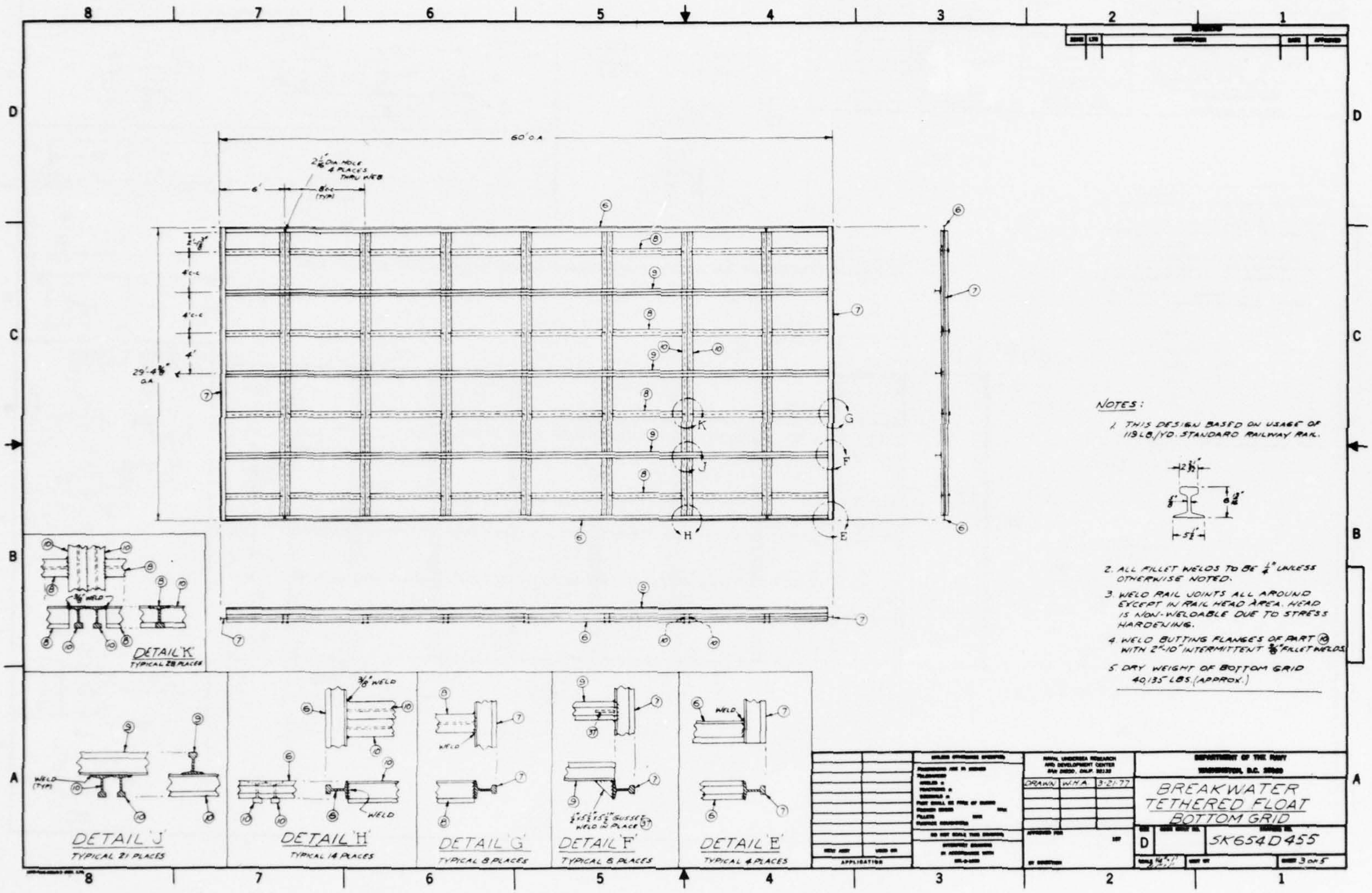

Figure 18. Tethered Float Breakwater ballast, bottom grid.

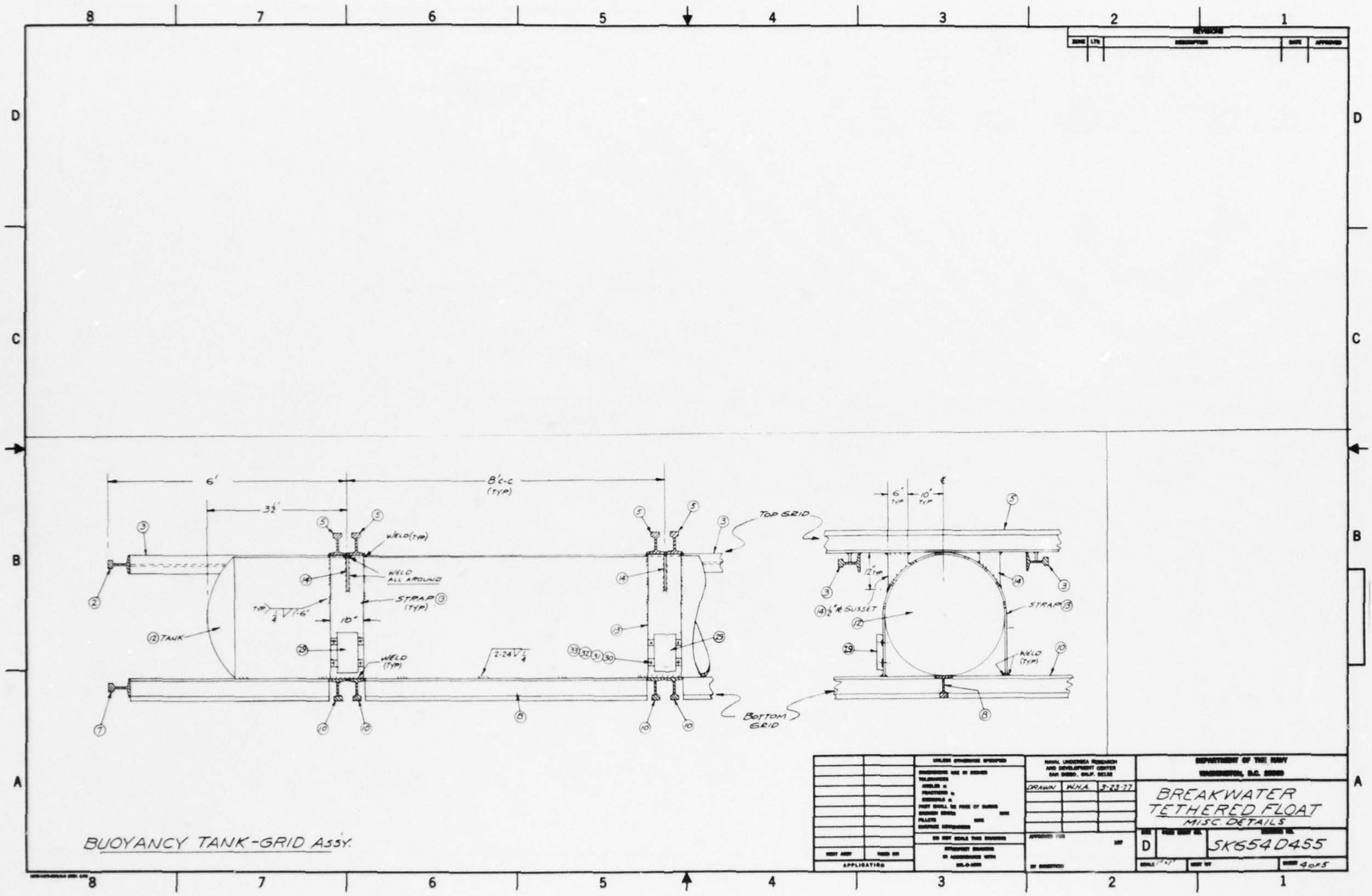

Figure 19. Tethered Float Breakwater ballast, miscellaneous details.

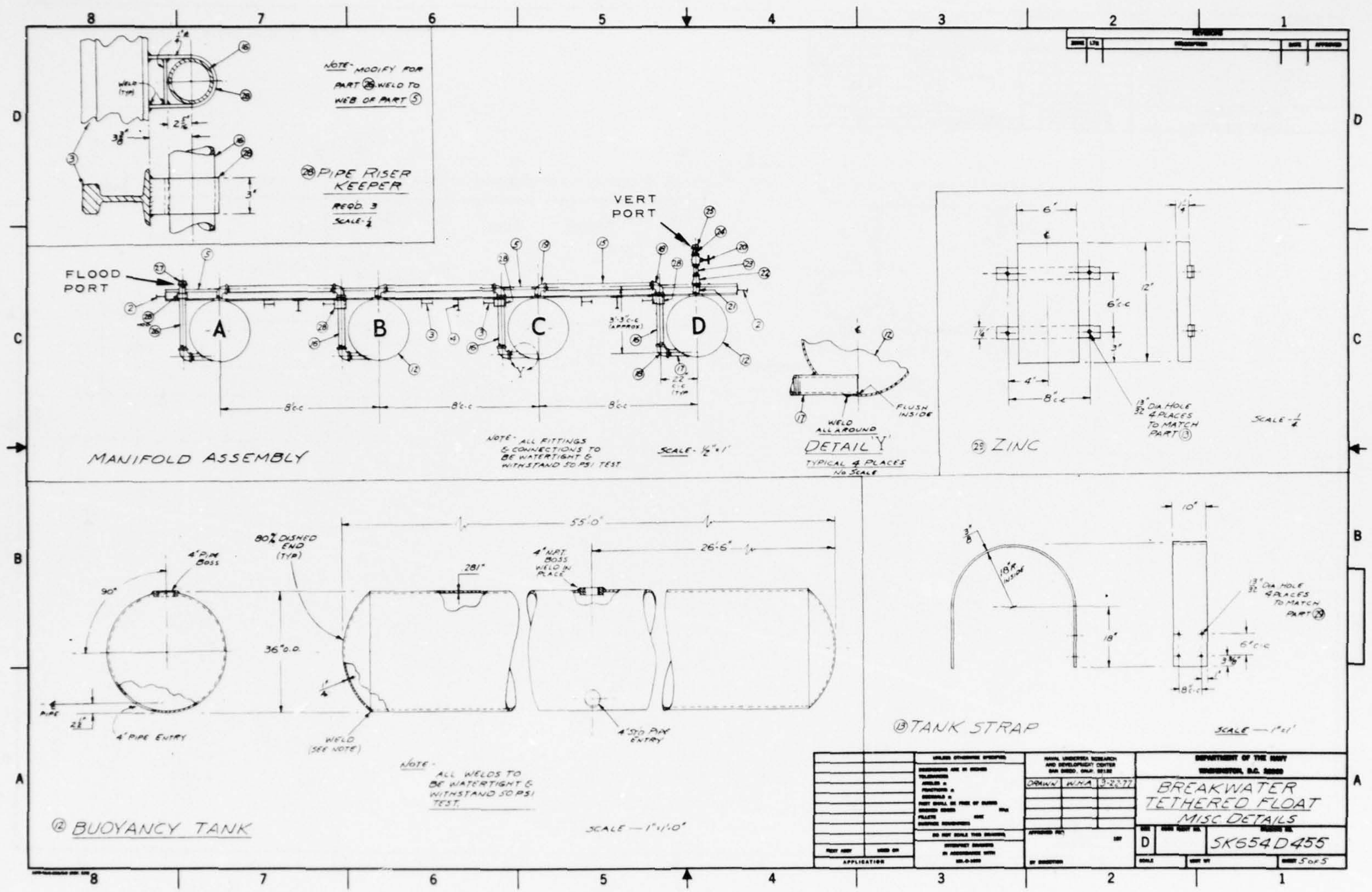

Figure 20. Tethered Float Breakwater ballast, miscellaneous details.

wall with 80 percent dished heads on each end) were secured to the bottom grid with straps formed from plate (See Figures 19 and 20). Twenty-eight sacrificial zinc anodes, weighing 24 lb each, were bolted to the straps for cathodic protection of the ballast assembly. These should last about a year.

The ballast tanks were interconnected across the center of the module with standard four inch steel pipe to form a manifold assembly. The bottom of one tank was joined to the top of the next for sequential deballasting of the system. Sequential deballasting of the tanks enables the floats to be resurfaced one row at a time. The low side of the frame remains on the bottom until the last tank is blown. This provides stability to the assembly and a method of control in open ocean. A two-inch valve at the top of one outboard cylinder provides an attachment point for the air supply and vent hose.

A weight calculation of the complete ballast section was made based on the fabrication drawings. The results are shown in Appendix I. Total dry weight of the assembly was 115,165 lb with an in-water weight of 100,194 lb, slightly over the required minimum of 96,000 lb. With a total buoyancy of 96,448 lb, the tension in each tether would be 29.3 lb (with ballast completely blown).

A stress analysis was made on the frame for various loading conditions. Bending stresses resulting from lifting the completed structure (ballast and floats) and deballasting tanks are given in Appendix J. The critical weld areas were also investigated. The steel rail provides a framework that is extremely rigid. All calculated stresses are far below the structural yield point of the material.

BALLAST FABRICATION

The two TFB Ocean Model ballast assemblies were fabricated by Balboa City Steel, San Diego, CA. Because of the overall size (30 x 60 ft), it was necessary to assemble each unit in two 15 x 60 ft pieces that would later be joined. Figures 21 and 22 show the formation of the top and bottom grids of the structure and placement of ballast tanks. Due to stress hardening of the steel rail and its general chemical composition, stainless steel weld rod (308L-16) was used throughout to achieve the desired strength. Typical frame construction is illustrated in Figures 23 and 24.

Some modifications were made to the original drawing package prior to construction. Because of material availability, the following substitutions were made:

1. 112 lb/yd rail for 119 lb/yd
2. .312 inch wall mild steel pipe for .281 inch wall (36 inch OD)
3. 5/16 inch semi-elliptical cylinder heads for 1/4 inch 80% dished heads.

The overall weight was to remain unchanged at approximately 115,200 lb.

When each half of the ballast was completed, it was transported by truck to the Naval Station at 32nd St, San Diego. There it was loaded on board an assembly barge (YC 1087) for the final stages of construction (Figures 25 and 26). The second part of the framework was aligned with the first (Figures 27 and 28) and the two halves joined. Splice plates, shown in Figures 29 and 30 were welded to each rail for added strength, since the

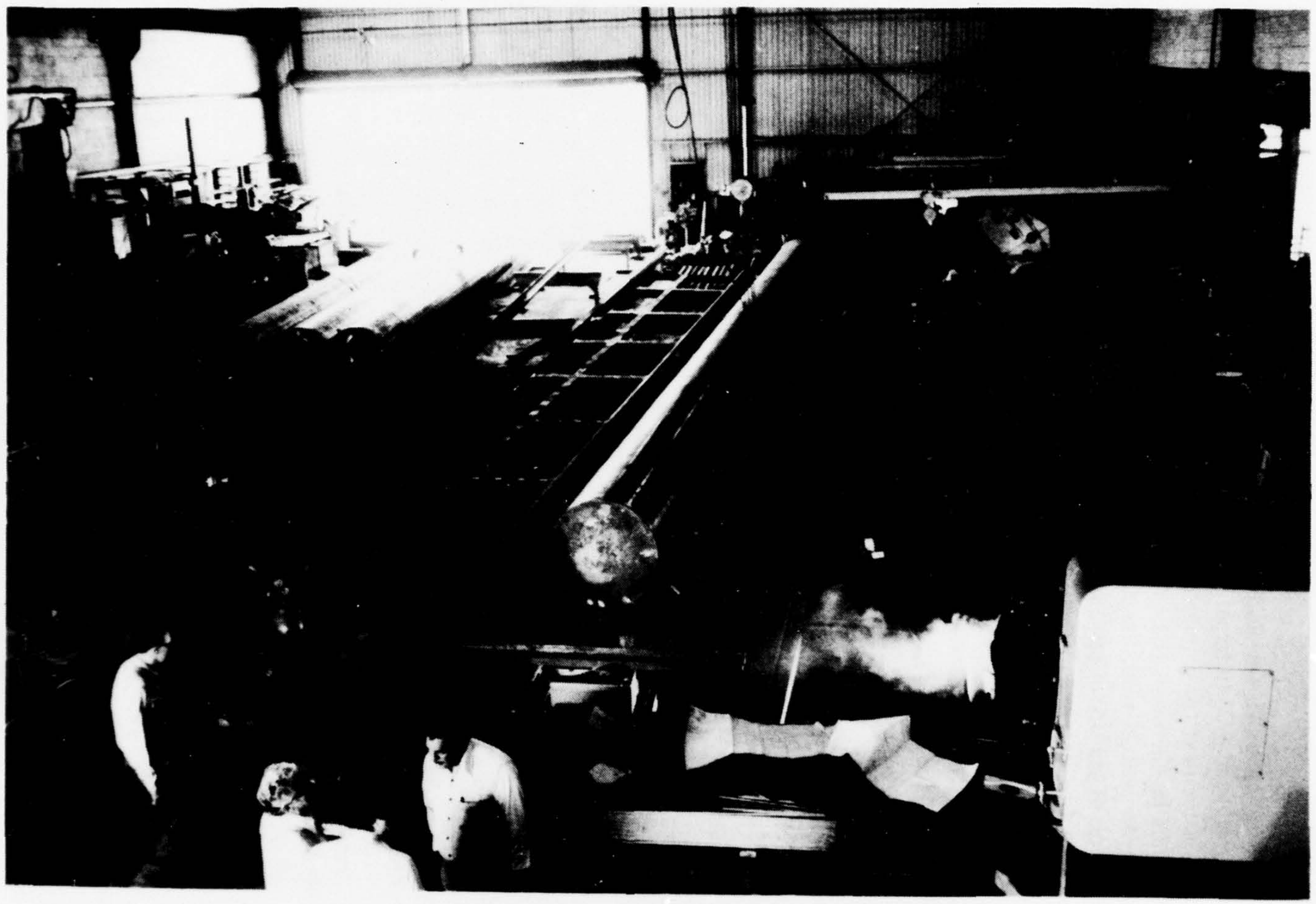

Figure 21. Fabrication of ballast, top and bottom grids.

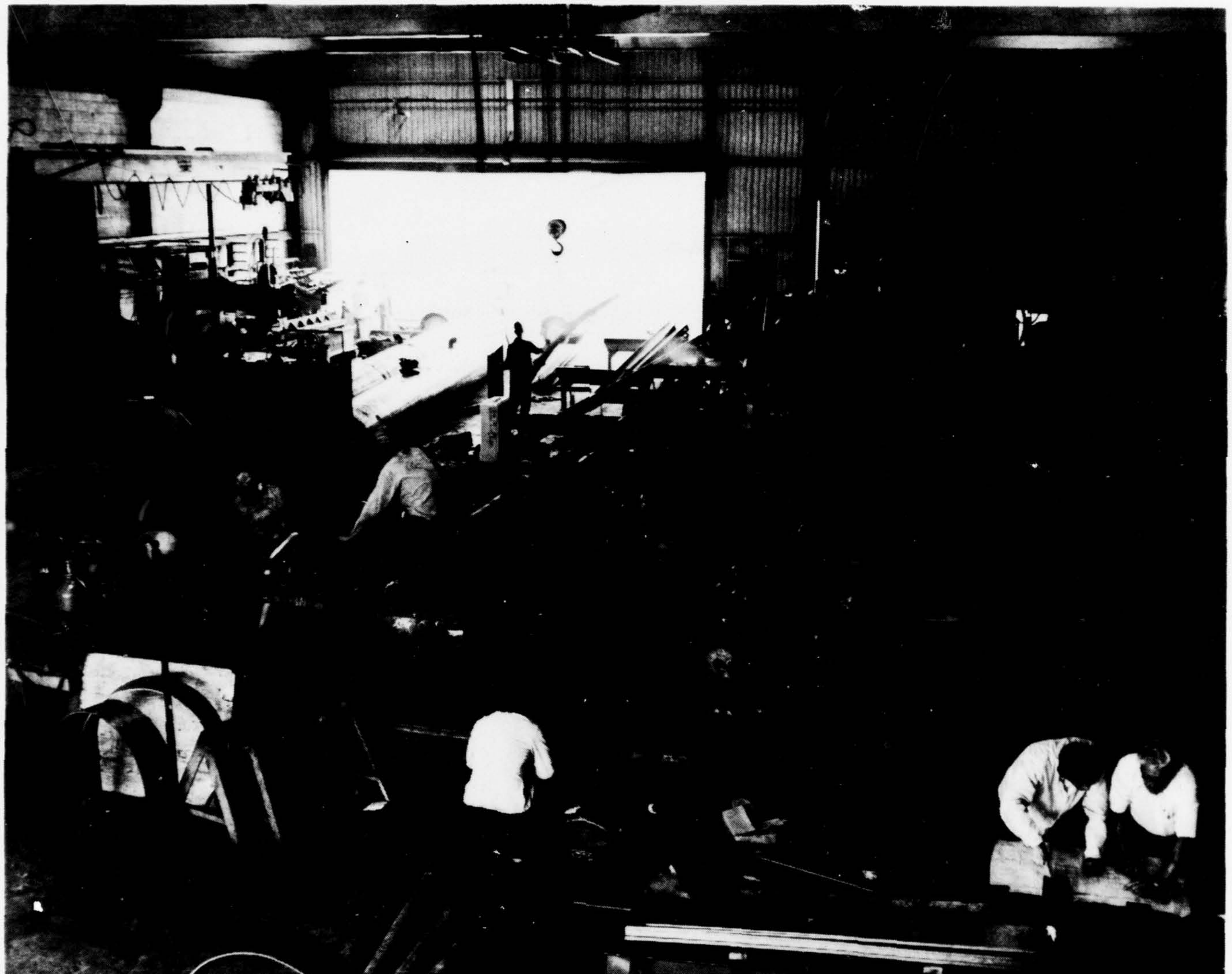

Figure 22. Ballast section assembly (15 ft by 60 ft)

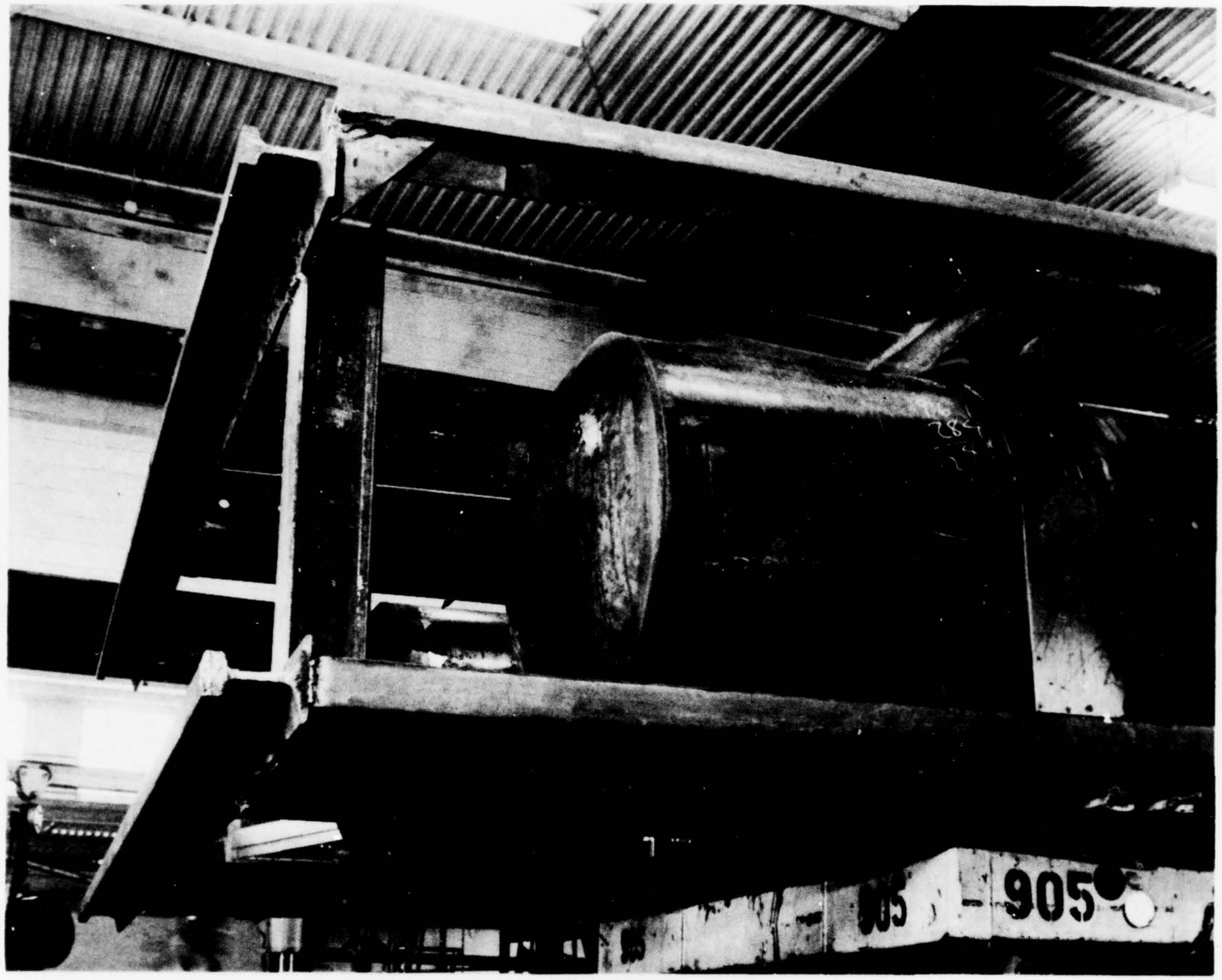

Figure 23. Typical ballast frame construction.

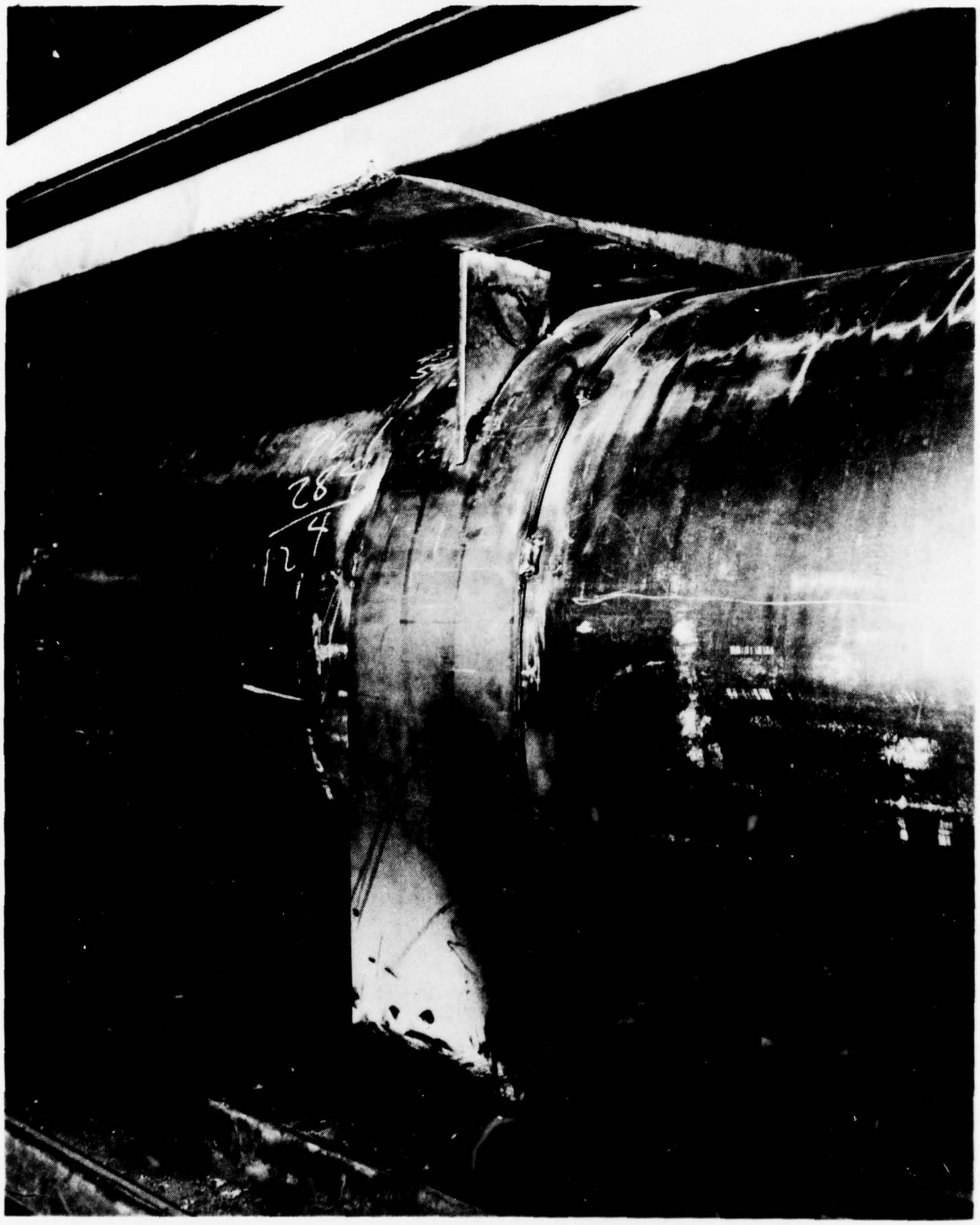

Figure 24. Tank straps.

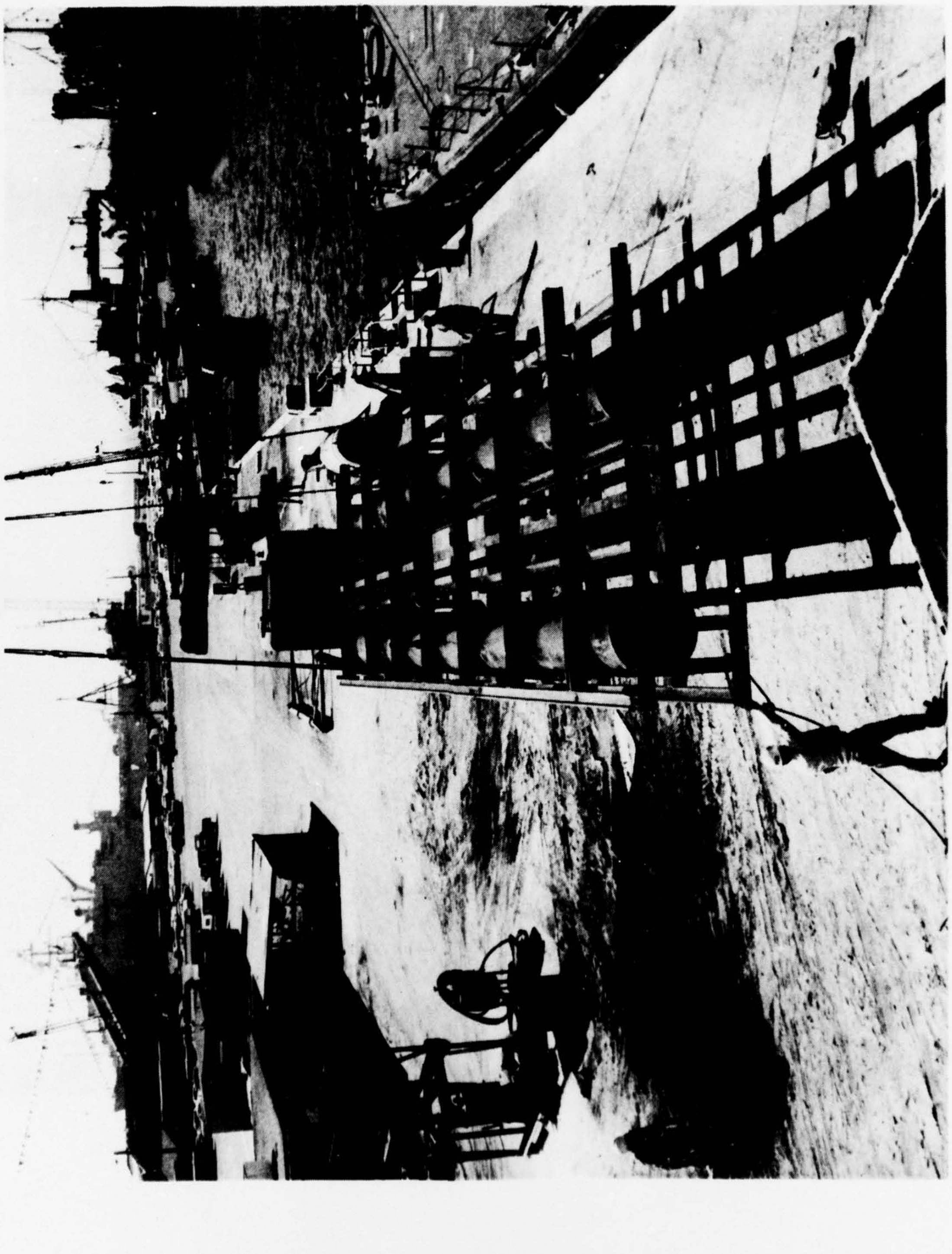

Figure 25. Transferring ballast section to assembly barge.

Figure 26. Underside of ballast section.

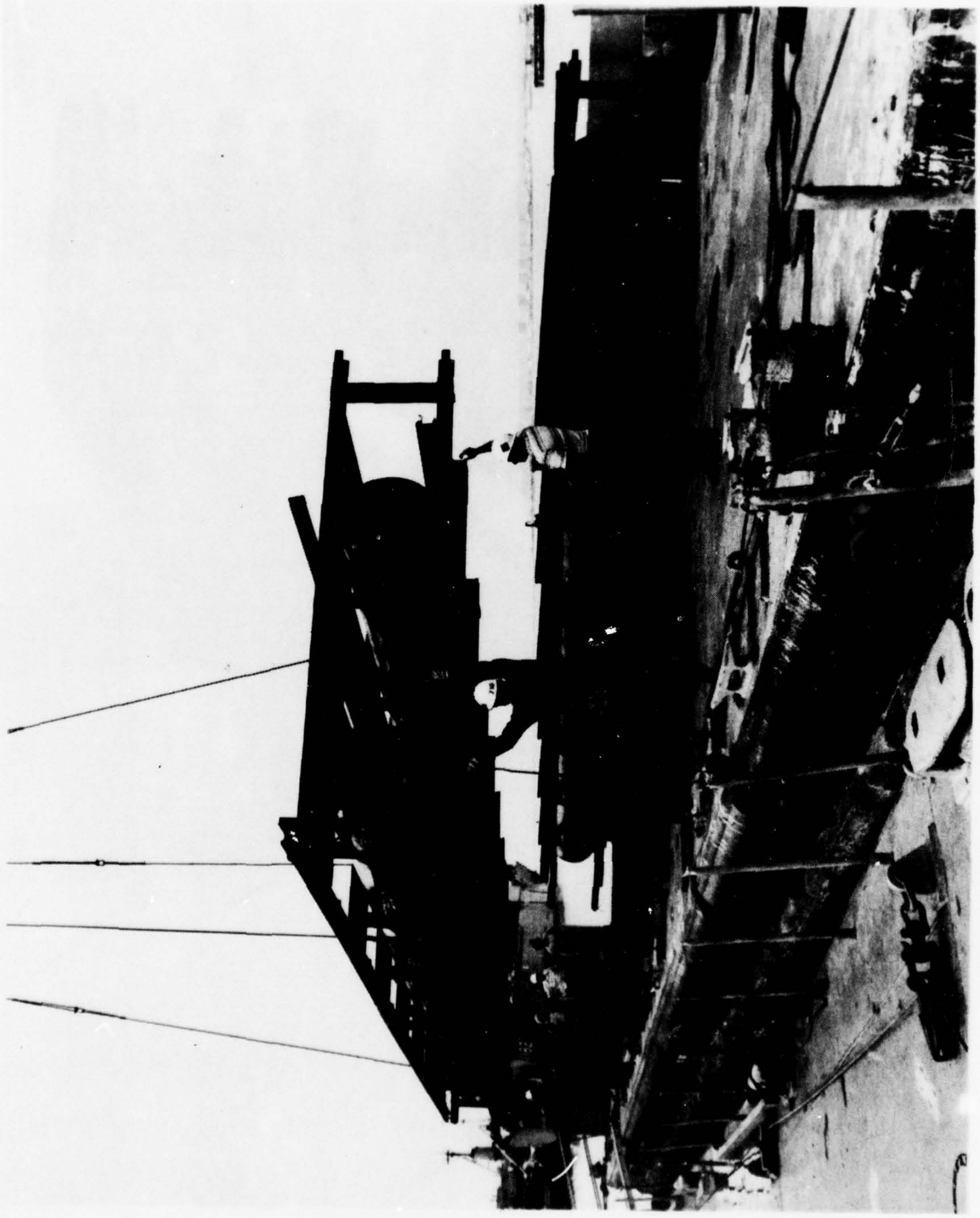

Figure 27. Aligning both halves of ballast assembly.

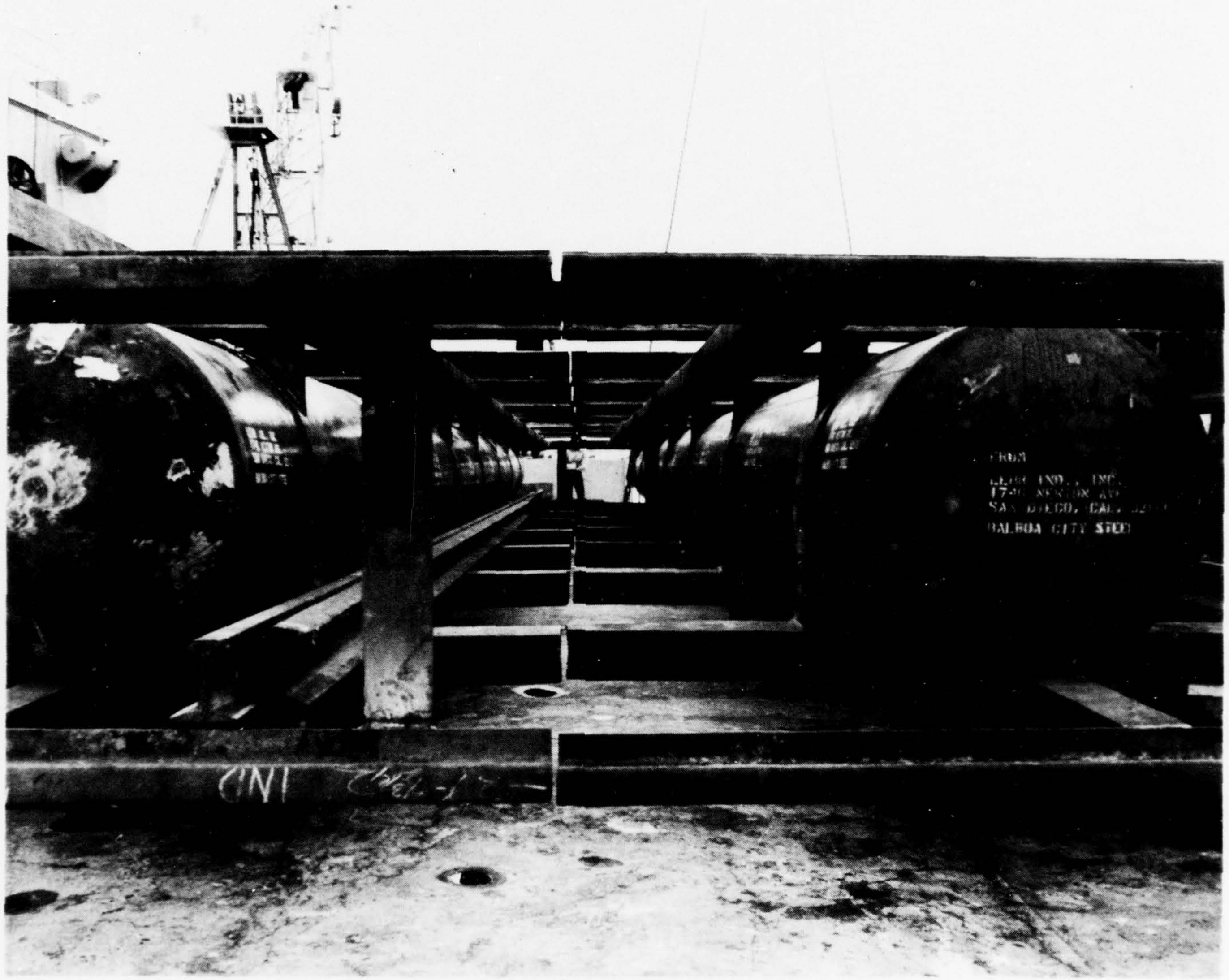

Figure 28. Ballast sections prior to joining.

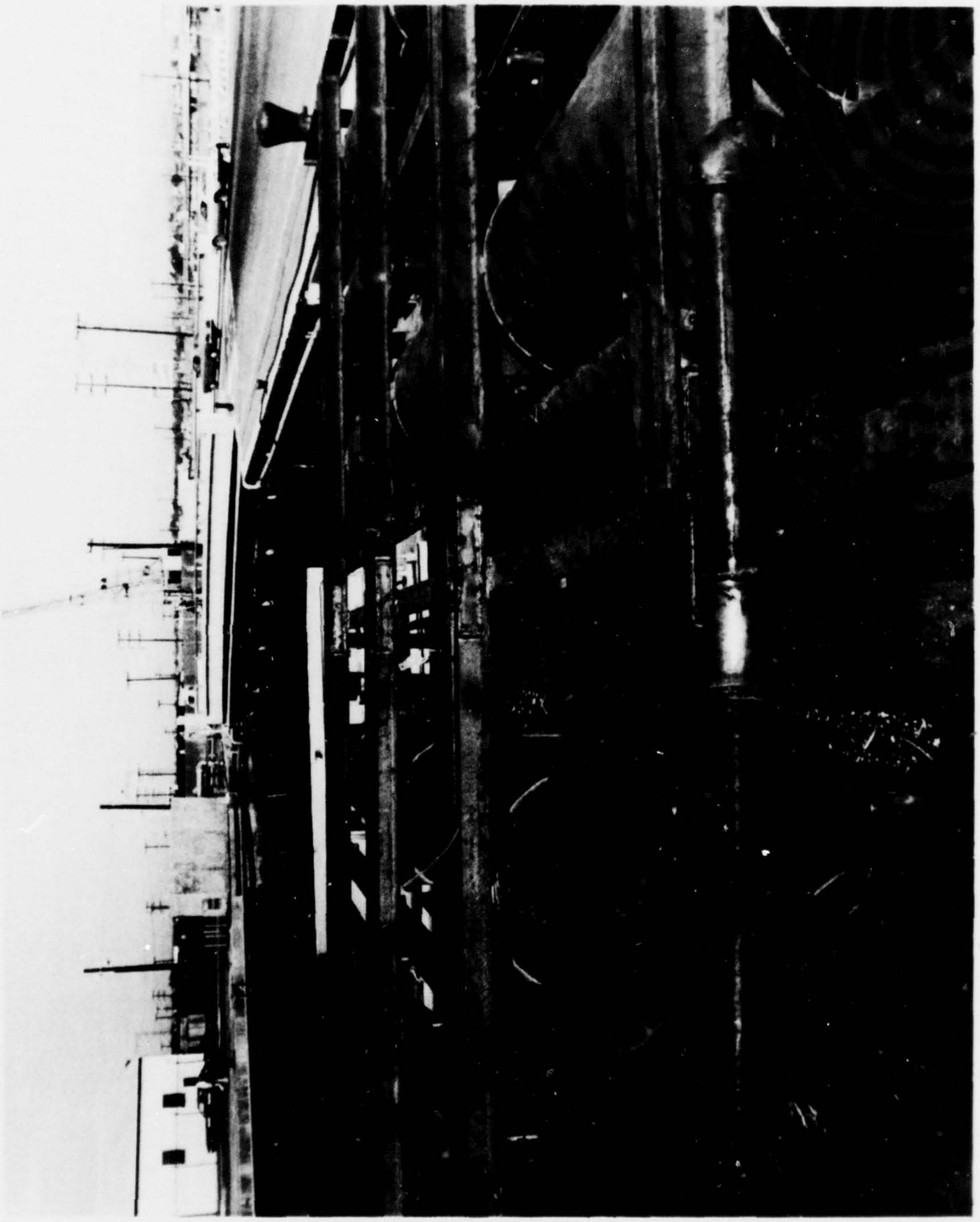

Figure 29. Top grid showing splice plates and interconnecting pipe.

Figure 30. Splice plates used to join rails.

rails themselves could not be completely connected. Appendix K is a calculation of bending stress in the section relying only on the splice plates for support. Zincs were bolted to each tank strip for corrosion protection (Figure 31). A portion of the four inch pipe that interconnects the ballast tanks is shown in Figures 32 and 33.

After the ballast assembly was completed, a 50 psi hydrostatic pressure test was conducted on the tanks and plumbing to insure watertight integrity of the system. Figure 33 shows the basic attachment of the airline and pressure gauge to the two inch valve on the outboard ballast tank. Pressure was held for 30 minutes. The tanks were deballasted using the pier air supply (Figure 34).

A 100 ton floating crane (YD-225) lowered the unit in the water for a weight verification (Figure 35). Ballast assembly No. 1 floated as shown in Figure 36. A complete review of material weights was conducted since the ballast alone with tanks dry should be about 4,000 lb negative. The weight of all pieces used in actual fabrication was checked. The assembly should weigh 114,885 lb as itemized in Appendix L. Because 112 lb/yd rail was used instead of 119 lb/yd for the majority of the structure, the unit was 3,658 lb light. One-hundred and eighty feet of rail were added to the frame (6,720 lb) to slightly increase the negative buoyancy. The final total weight of the ballast assembly was 117,950 lb. Upon completion, the assembly barge was towed to the NOSC pier where attachment of floats and tethers was performed..

Procurement specifications for Ocean Model tethers, floats, and ballas assemblies are detailed in Reference 9.

9. NOSC TN 361: Tethered Float Breakwater, Annual Report FY77; J. D. Clinkenbeard and A. R. Estabrook, March 1978.

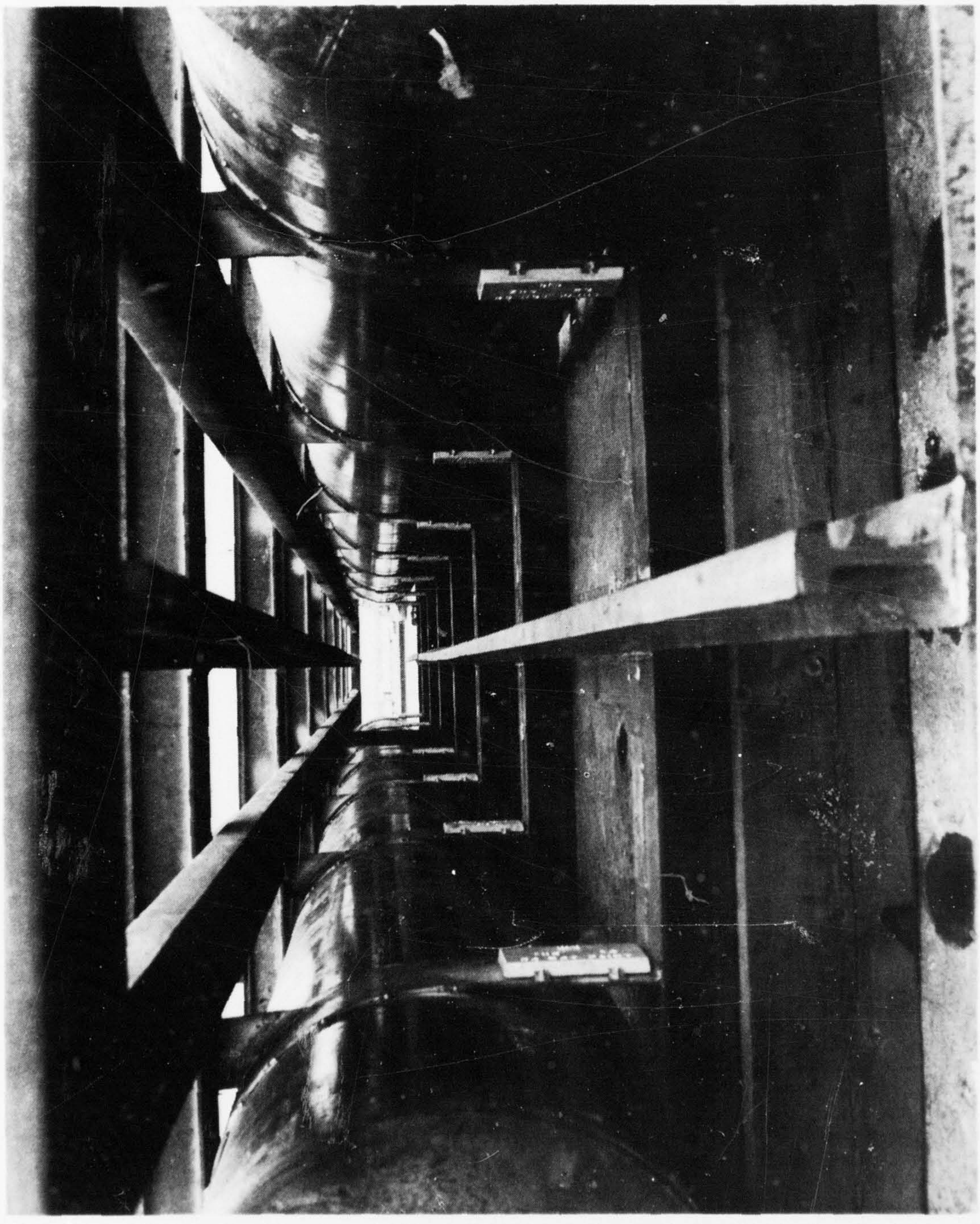

Figure 31. Zincs installed on tank straps.

Figure 32. Interconnecting pipe for ballast tanks, flood port.

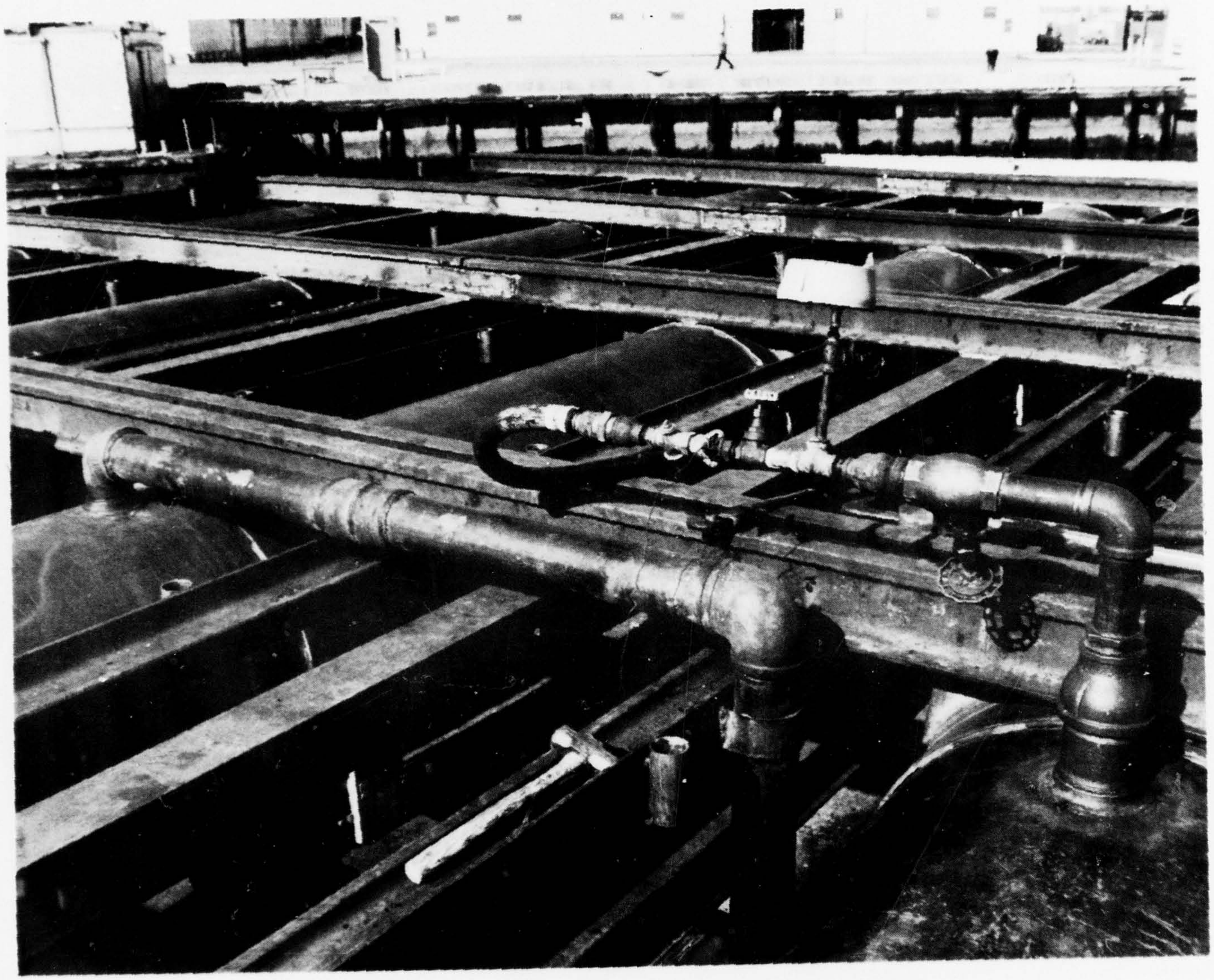

Figure 33. Interconnecting pipe, and equipment for hydrostatic test.

Figure 34. Deballasting tanks after hydrostatic test.

Figure 35. Launching of ballast assembly to verify in-water weight.

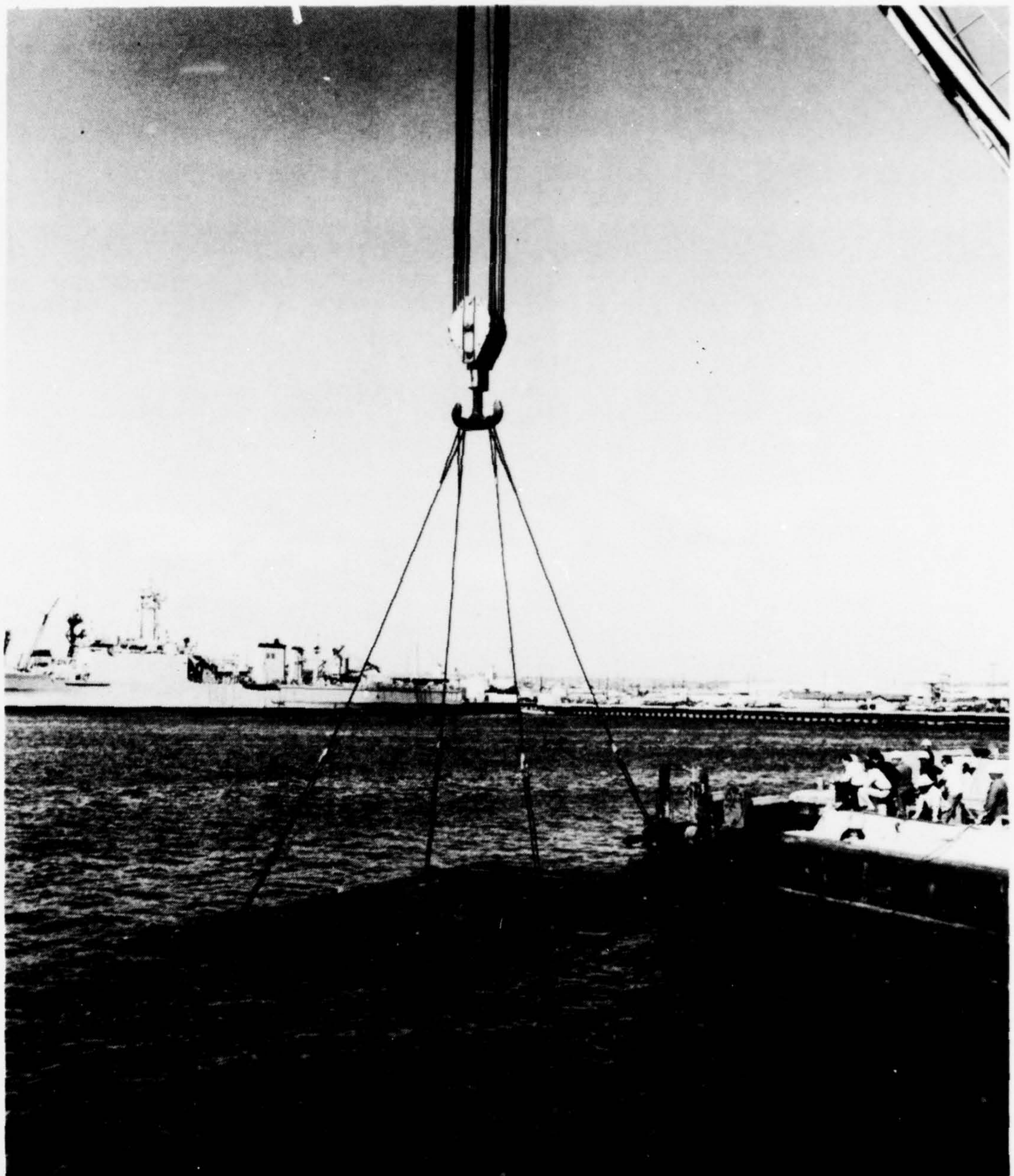

Figure 36. Ballast assembly showing positive buoyancy.

MODULE ASSEMBLY AND EVALUATION

MODULE ASSEMBLY

The three major components (ballast, floats and tethers) of the Tethered Float Breakwater module were assembled on board a cargo barge, YC 1087, berthed at the NOSC pier. A mobile crane was used to position the tire floats on the ballast frame (Figures 37 and 38). The floats were simply stacked in a convenient location that would not interfere with the tether terminations, as shown in Figure 39. Figures 40, 41, and 42 illustrate the method of attaching the float to the ballast with the synthetic tether. The soft eye of the tether is passed through the bail of the float; the boot is inserted through the eye and the slack removed. The boot is placed in a tether socket on the top grid of the ballast frame and a steel pin is inserted through the impregnated eye to restrain the tether assembly.

With all 128 tire floats attached to the ballast, a 100 ton floating crane, YD 225, transferred the completed TFB assembly from the barge to the water (Figures 43, 44, and 45). Total weight of each module was approximately 178,750 pounds. On 21 February 1978, the first Ocean Model prototype was temporarily installed off the NOSC pier in San Diego Bay. The inclined bottom ranged in depth from 20 to 30 feet sloping away from the pier. The purpose of this installation was two-fold: 1) to provide a short-term (about one month) test and predeployment handling evaluation period prior to the Imperial Beach implantment, and 2) to free work area on the YC-1087 for the final assembly of the second module.

INTERIM TEST AND EVALUATION

An attempt was made to deballast TFB Module No. 1 (installed at the end of the NOSC pier) to evaluate the proposed recovery technique. Because of the inclined bottom, difficulty was experienced in resurfacing the assembly in a horizontal position (Figure 46). Sufficient water could not be removed from the ballast tanks with the existing plumbing system, which was originally designed for use on a flat seafloor. Water could only be evacuated between the upper end of the cylinders and the point at which the water level coincided with the four inch pipe at the base of the tank.

It was decided to make the following modifications to the valves and pipes that interconnect the four ballast tanks on module No. 2 still being assembled on board the YC barge:

a. One-half inch valves were installed on each end of all tanks to bleed off trapped air (these can also be used as an air connection for deballasting) (Figure 47).

b. Two inch diameter standpipes were installed at each end of the tanks to insure that all water could be evacuated whatever the orientation of the tanks.

c. The ballast tanks were separated by removing the four inch diameter horizontal pipes connecting the cylinders. A four inch gate valve was installed on the vent

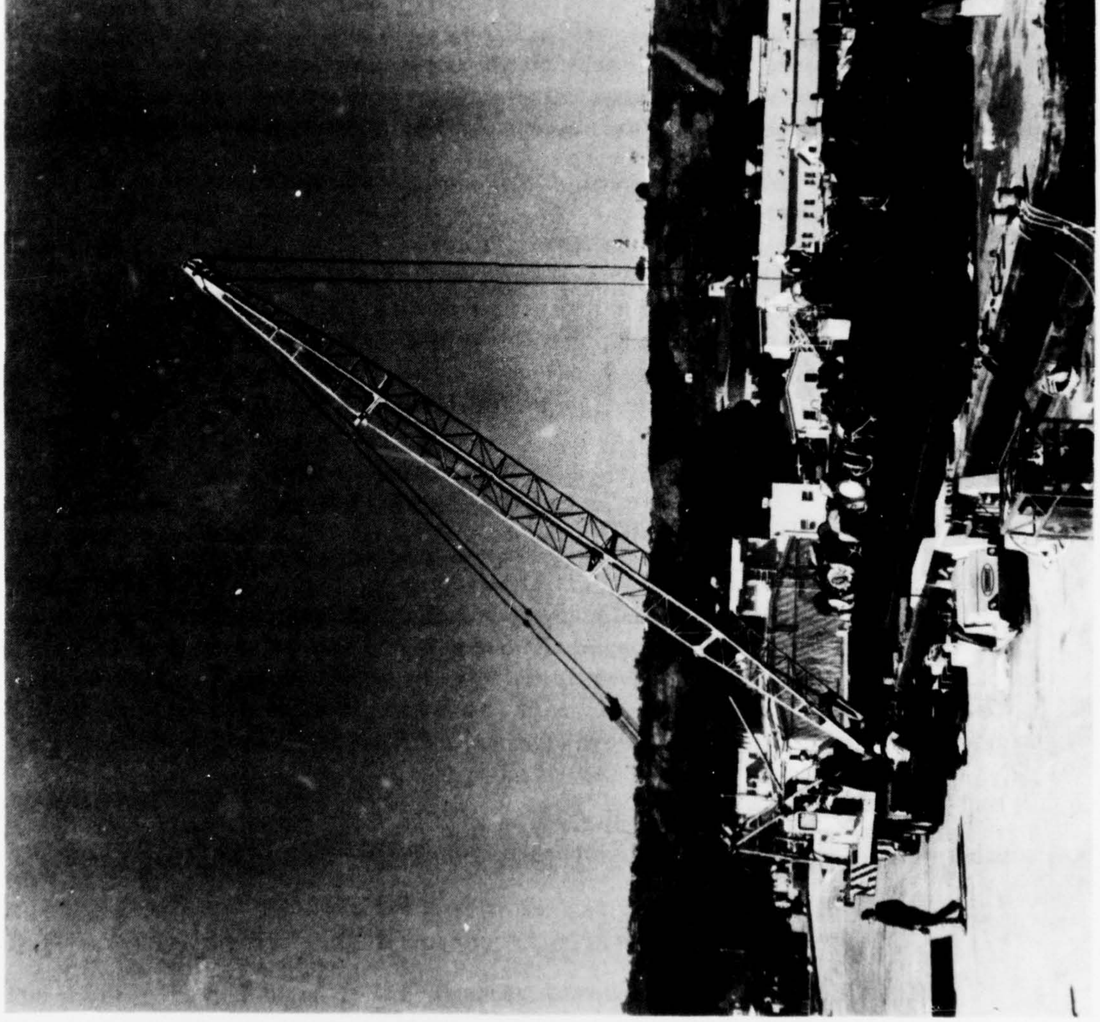

Figure 37. Positioning floats with mobil crane.

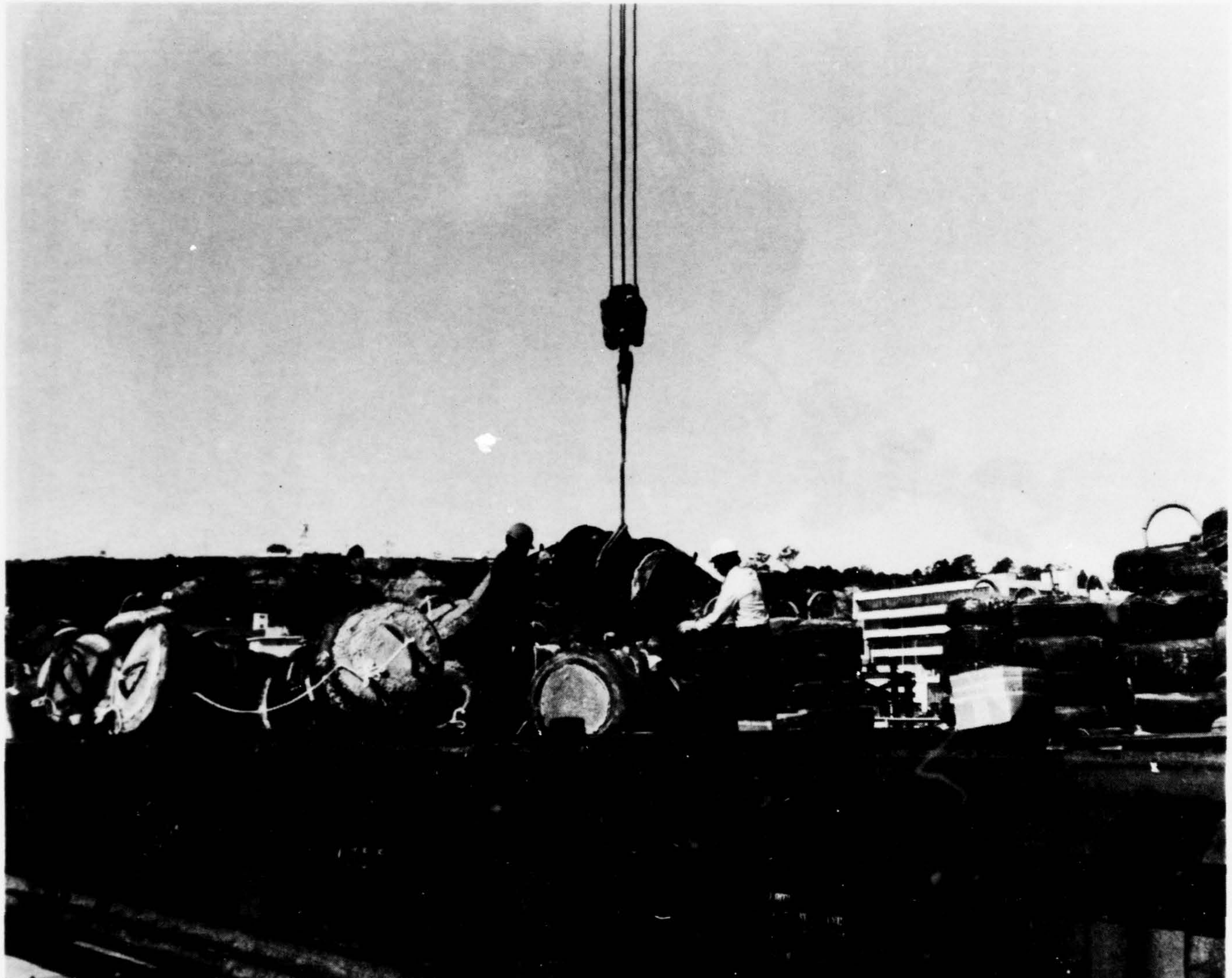

Figure 38. Positioning floats on ballast.

Figure 39. Tire float placement.

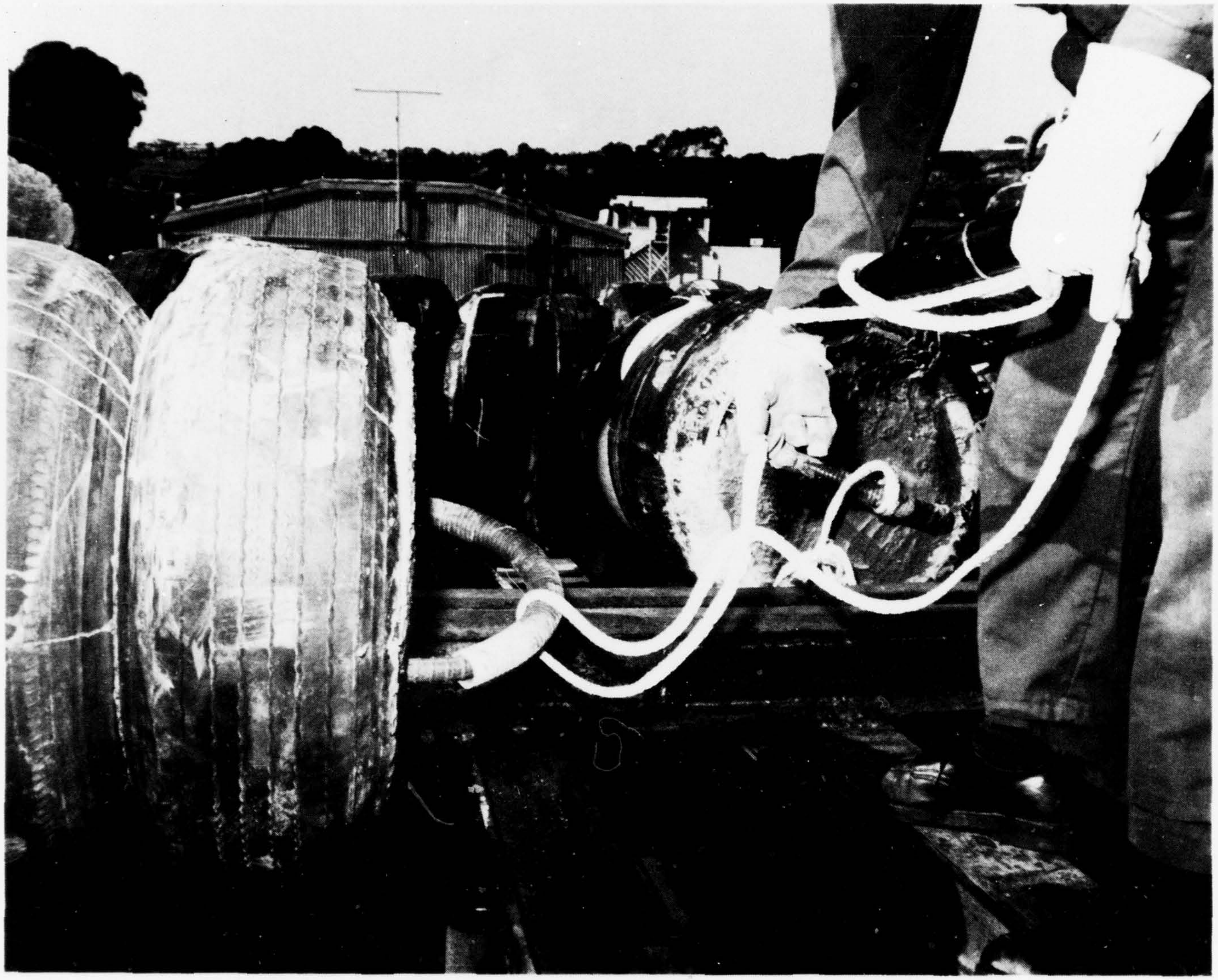

Figure 40. Attaching tether to float.

Figure 41. Inserting boot in tether socket.

Figure 42. Tether assembly with retaining pin in place.

Figure 43. Launching TFB Ocean Model with floating crane.

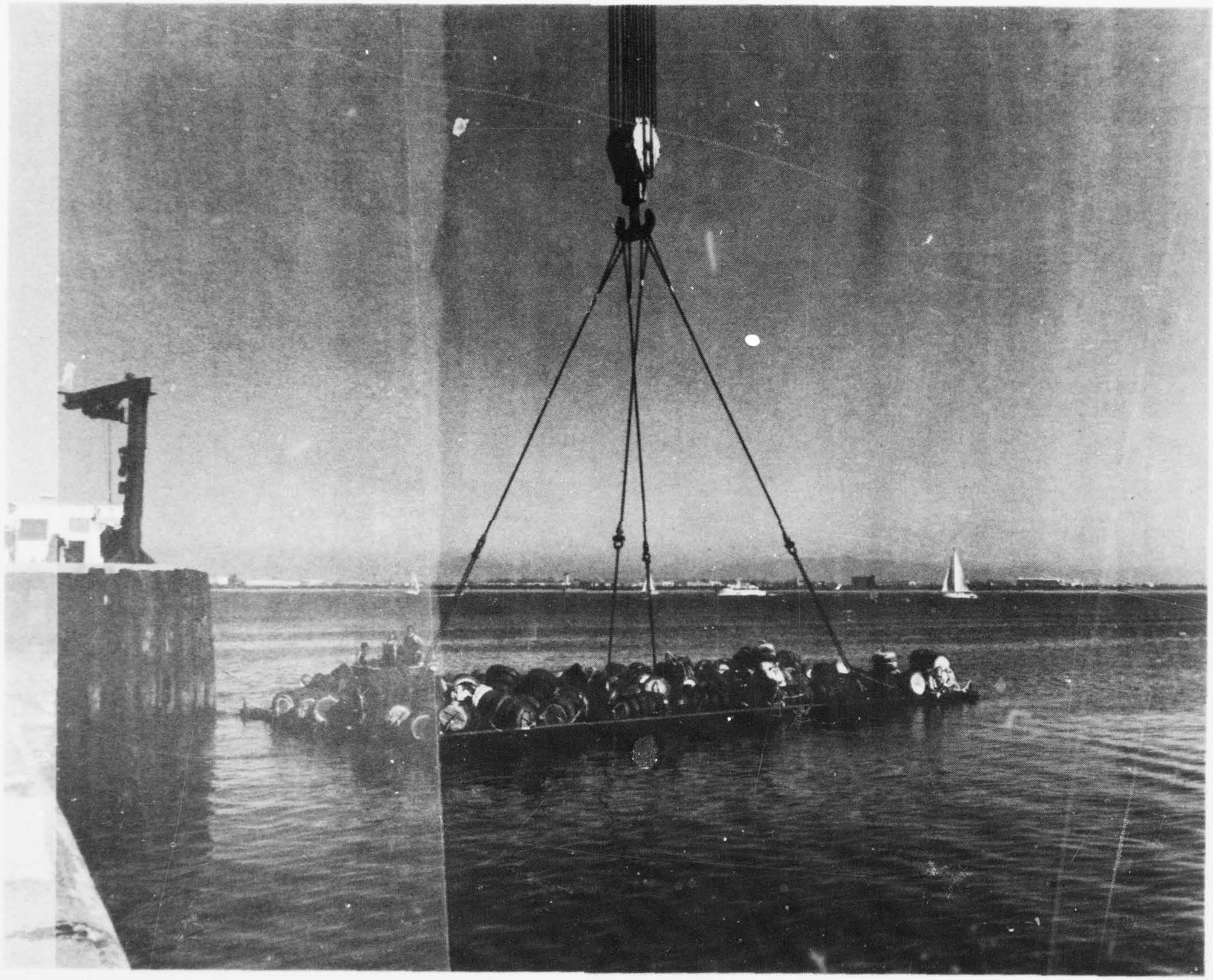

Figure 44. Positioning module in water.

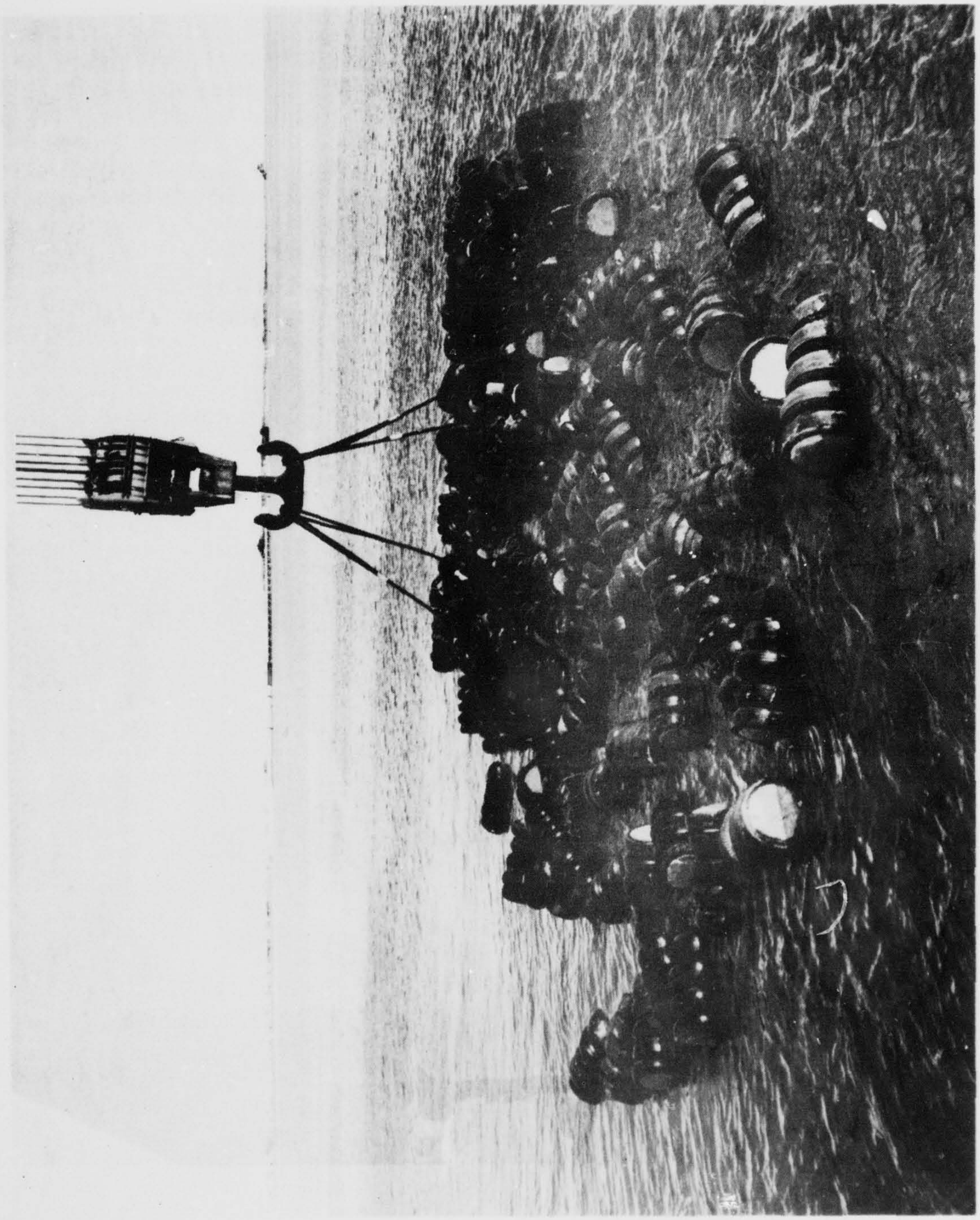

Figure 45. Transferring weight of ballast to tethers.

Figure 46. Attempt to resurface module No. 1.

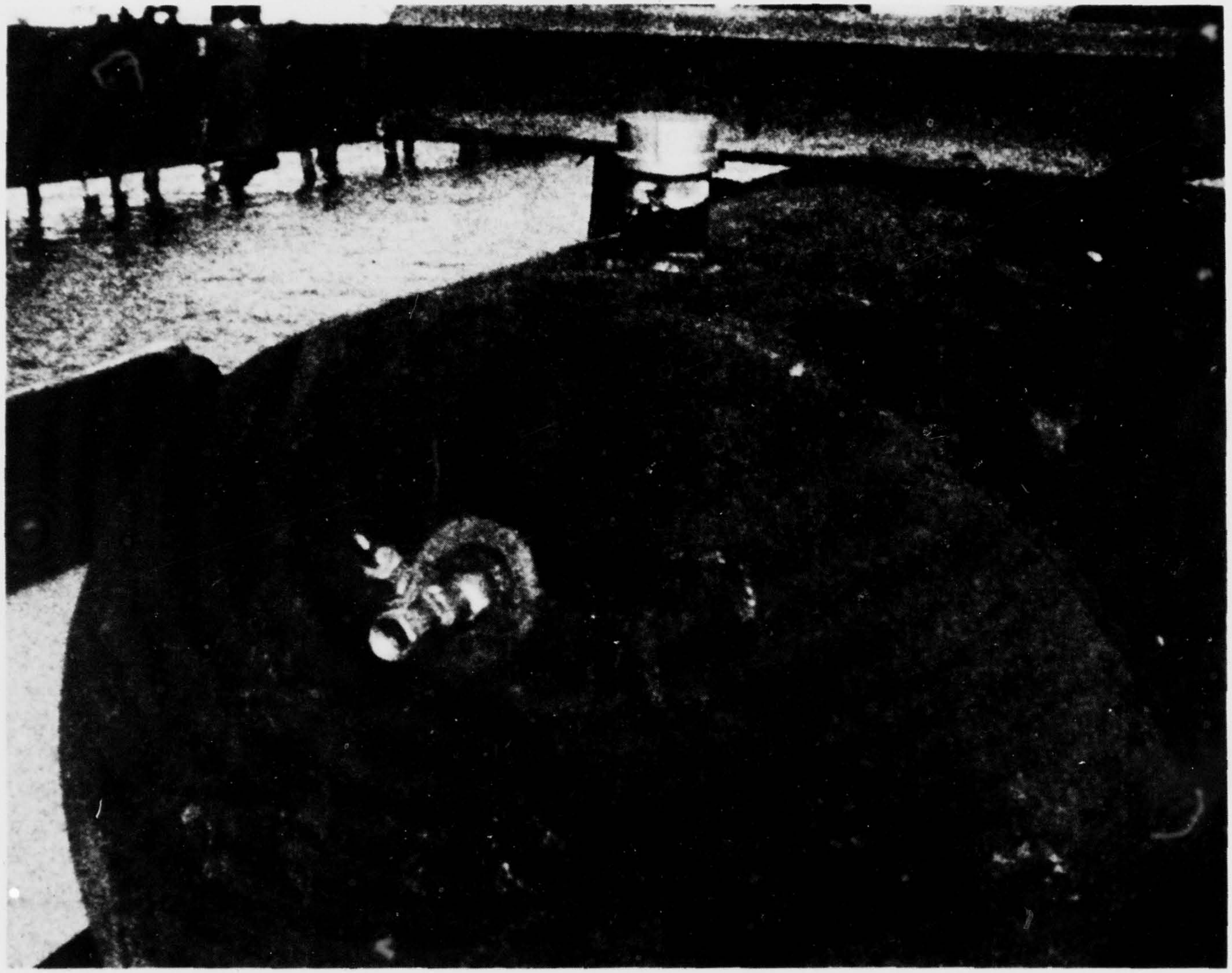

Figure 47. One half inch valve and standpipe modification.

port of each tank. Ever-tite® quick disconnects for four inch heavy duty suction hose (Uniroyal® type P-1196) were added to both the flood and vent ports. See Figures 48 and 49. The new configuration allows the four ballast tanks to be connected in any desirable combination and selectively vented. Figure 50 illustrates the new interconnect hose and the two inch vent hose previously mentiontioned.

Module No. 1 was recovered from the bay (Figure 51) for identical modification and module No. 2 installed in its place. All 128 tire floats were removed from the frame before retrieving the ballast. This prevented anticipated damage to tethers and terminations. Spherical buoys (58 inch diameter) attached to each end of the framework provided additional buoyancy required to surface the unit in a horizontal mode.

Figure 48. Four inch valve with quick disconnect fitting, vent port.

Figure 49. Hose fittings on four inch flood port and two inch vent port.

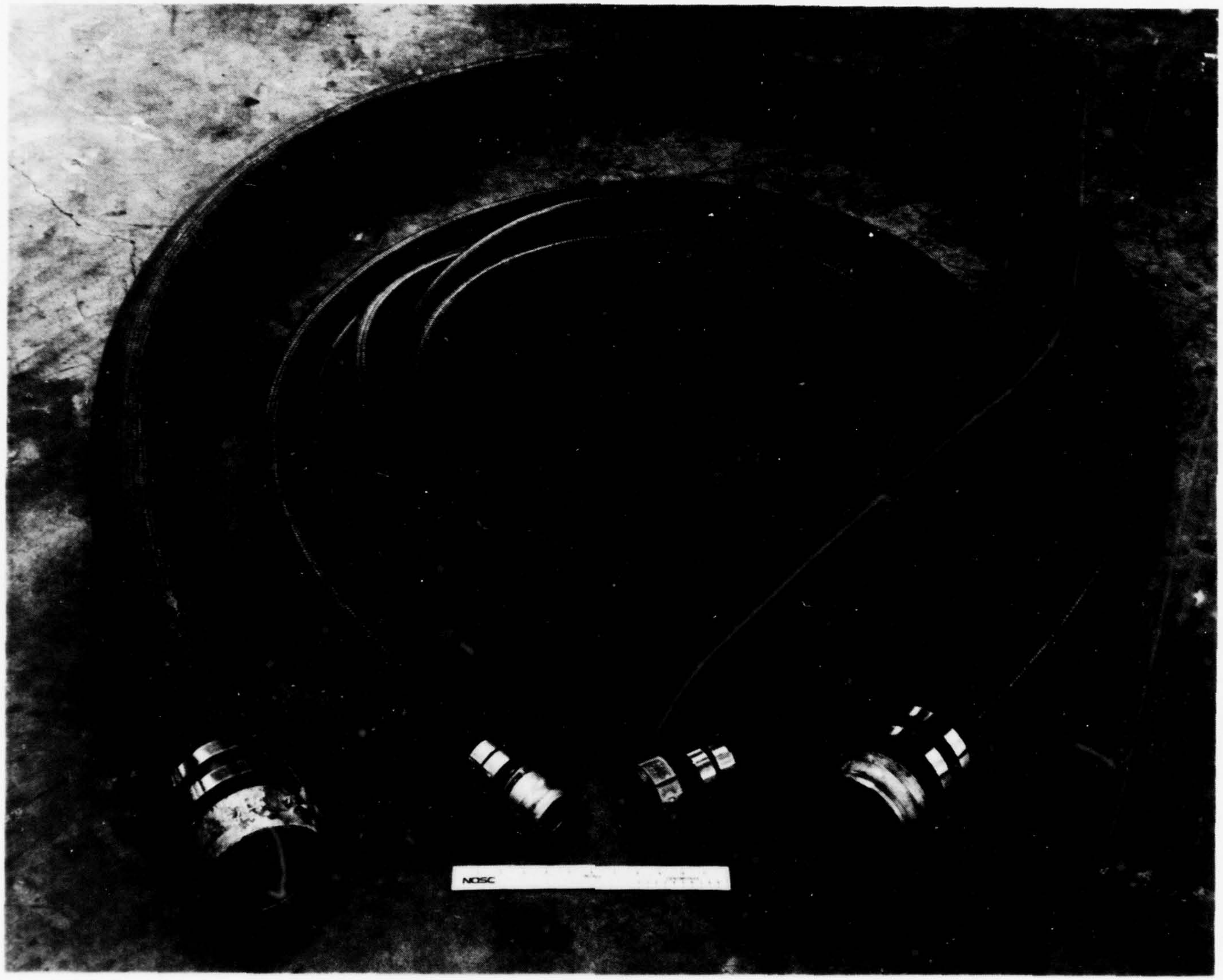

Figure 50. Interconnect and vent hoses.

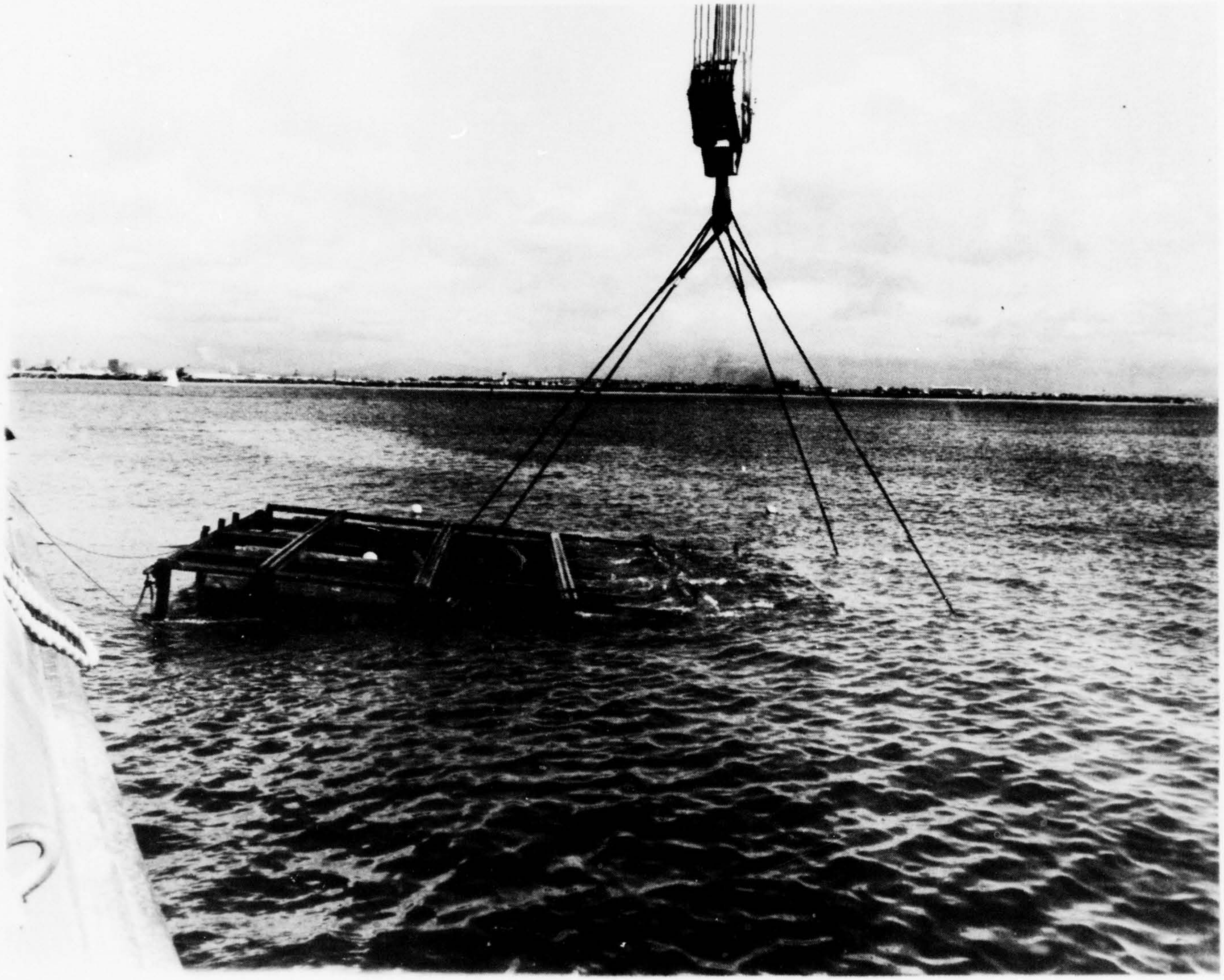

Figure 51. Recovery of TFB Module No. 1.

TOWING TEST

On 30 March 1978, TFB Module No. 2, previously installed off the NOSC pier, was resurfaced without difficulty (Figure 52) using standard deballasting procedures (ref appendix M). A limited towing experiment was then performed. The ballast tanks were oriented in a longitudinal position with the tow bridle attached to the end of the ballast (Figure 53). The Navy Tug Canonchet (YTB 823), was used to tow the module in San Diego Bay for approximately 30 minutes (Figure 54). Speeds of two to three-and-one-half knots were attained without difficulty. The single assembly was easily maneuverable with a short tow line. The tire floats streamed aft in a uniform pattern without the tethers becoming entangled (Figures 55 and 56). Following these tests, the module was reinstalled in its original location, submerged, off the NOSC pier.

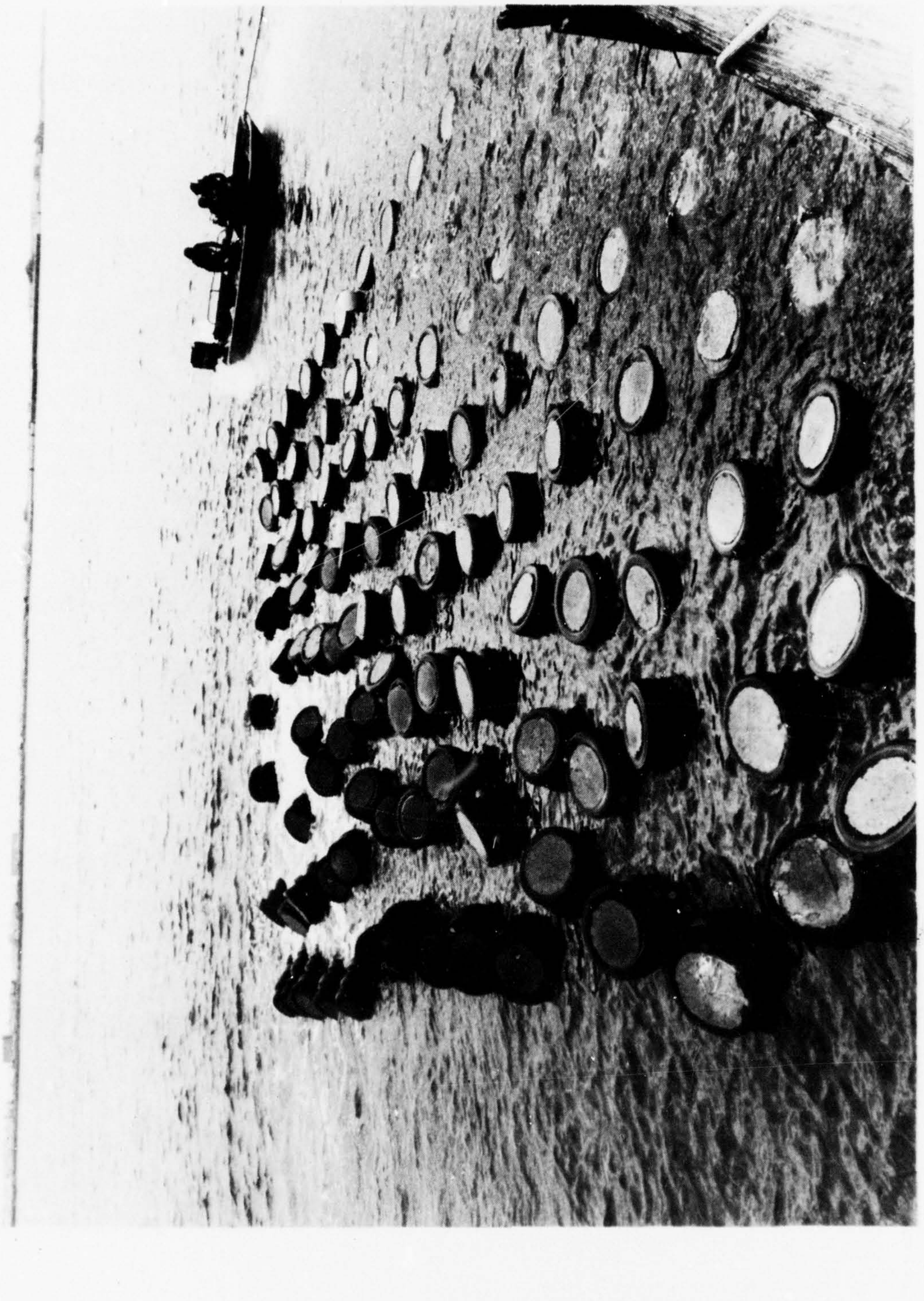

Figure 52. Resurfacing Module No. 2 for towing test.

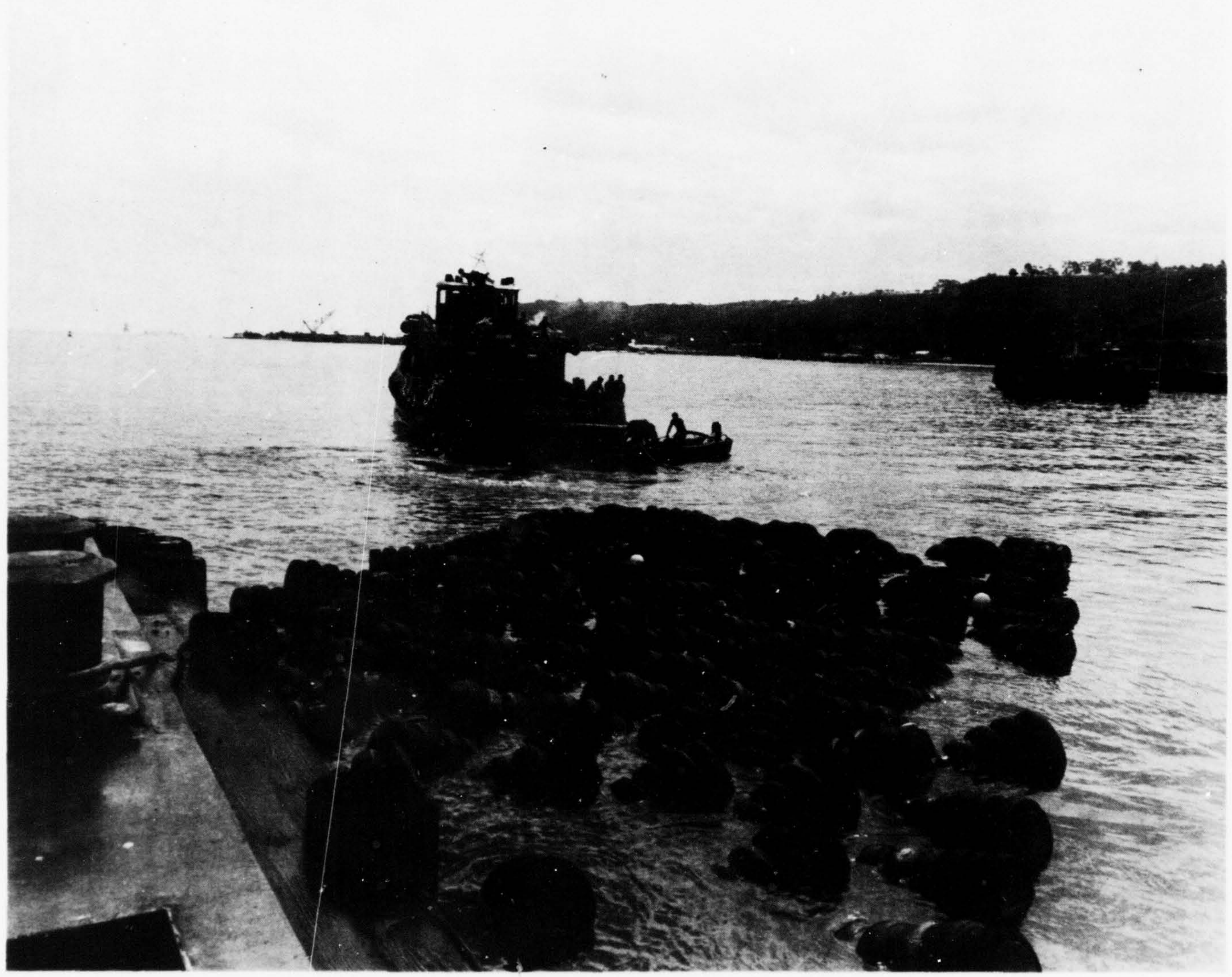

Figure 53. Attaching tow bridle to tug.

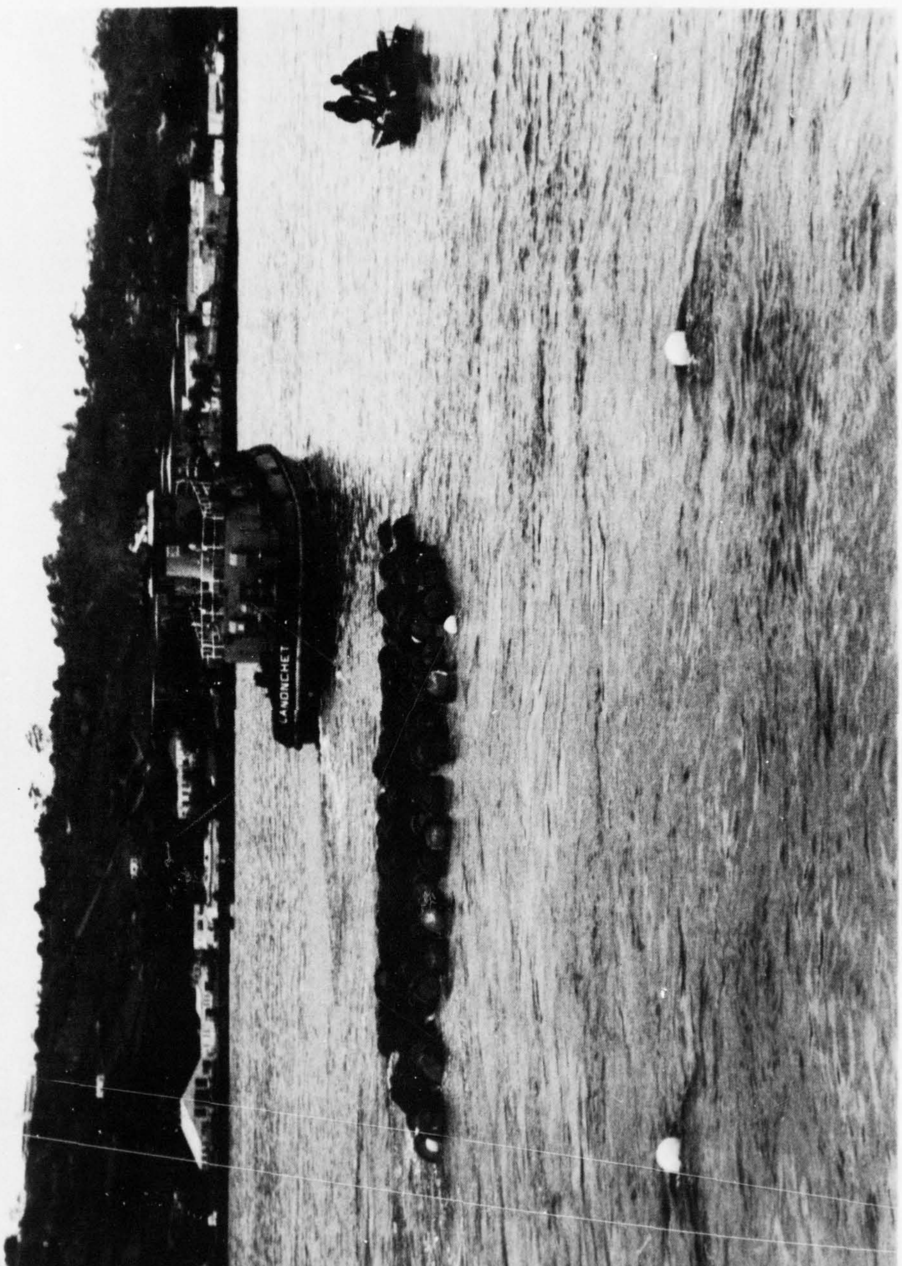

Figure 54. Towing TFB module at speed of two knots.

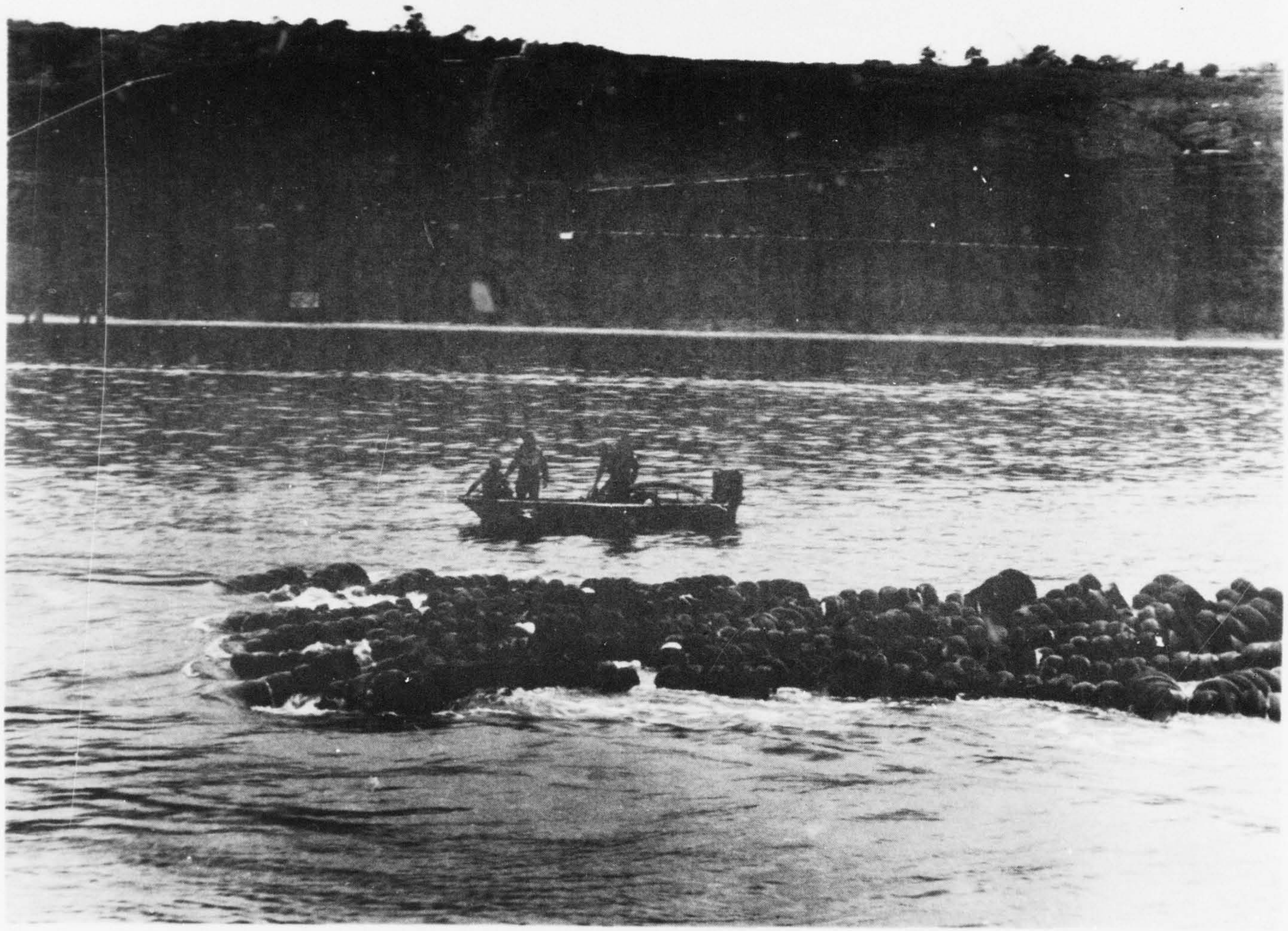

Figure 55. TFB assembly under tow.

Figure 56. Lead row of tire floats during tow.

OCEAN EXPERIMENT

TFB OCEAN MODEL INSTALLATION

The Tethered Float Breakwater (TFB) Ocean Model was installed off Imperial Beach, CA on 12 April 1978. The test site location, 32°35'15"N, 117°08'10"W, was 400 yards off shore. It has a firm, flat sandy bottom, a water depth of 25 feet at mean lower low water, an average wave height of two to four feet, and a wave period of six to ten seconds. The area is subjected to open ocean waves throughout the year, ranging in direction from northwest in the winter to south in summer.

The installation procedures, detailed in Appendix M, required one day to stage and prepare both TFB modules, and the following day to tow the modules to the test site and ballast them down.

Module No. 2, which was previously installed off NOSC pier Bravo for short-term test and evaluation, was refloated on the morning of 11 April 1978 (Figure 57). Four tag lines were attached to the ballast frame and passed to piers Alpha and Bravo. After installing the hoses which interconnect the four ballast tanks, opening the necessary valves and attaching the airline, the module was deballasted using the pier air supply. The unit was free from the bottom in 39 minutes. It was then maneuvered by the hand-held tag lines to the mooring station between Alpha and Bravo piers and secured (Figure 58). All hoses were then removed.

Module No. 1 was launched using the YD-225, a 100 ton floating crane. The assembly barge (YC-1087) was positioned alongside the YD, lifting slings were attached to the ballast (Figure 59) and the unit transferred to the water in its staging position (Figures 60 and 61). This module was also secured for overnight berthing (Figure 62). The inter-module and forward towing bridles (Figure 63) were then attached.

The tandem tow of the TFB modules to the Imperial Beach site began at 0633 hours on 12 April. After making up the tow bridle to the tug (Figure 64) and casting off the mooring lines, the PT&S tug CORONADO (twin screw, 920 horsepower, 64 feet long) began the nine and one-half mile journey from the NOSC pier to the test site (Figure 65). The tug averaged a speed of one knot between the pier and buoy No. 6. Upon rounding the channel marker (Figure 66), 350 feet of towline was streamed out, and a dynomometer inserted to record towing forces (Figure 67). Speeds and corresponding drag forces are tabulated below.

Engine RPM	Speed (kt)	Drag (lb)
1500	1.89	4500
1750	2.53	5500
1900	3.16	7000

Appendix N shows sample drag calculations based on effective frontal area of the modules.

Figure 57. Refloating of Module No. 2.

Figure 58. Staging Module No. 2 at NOSC pier.

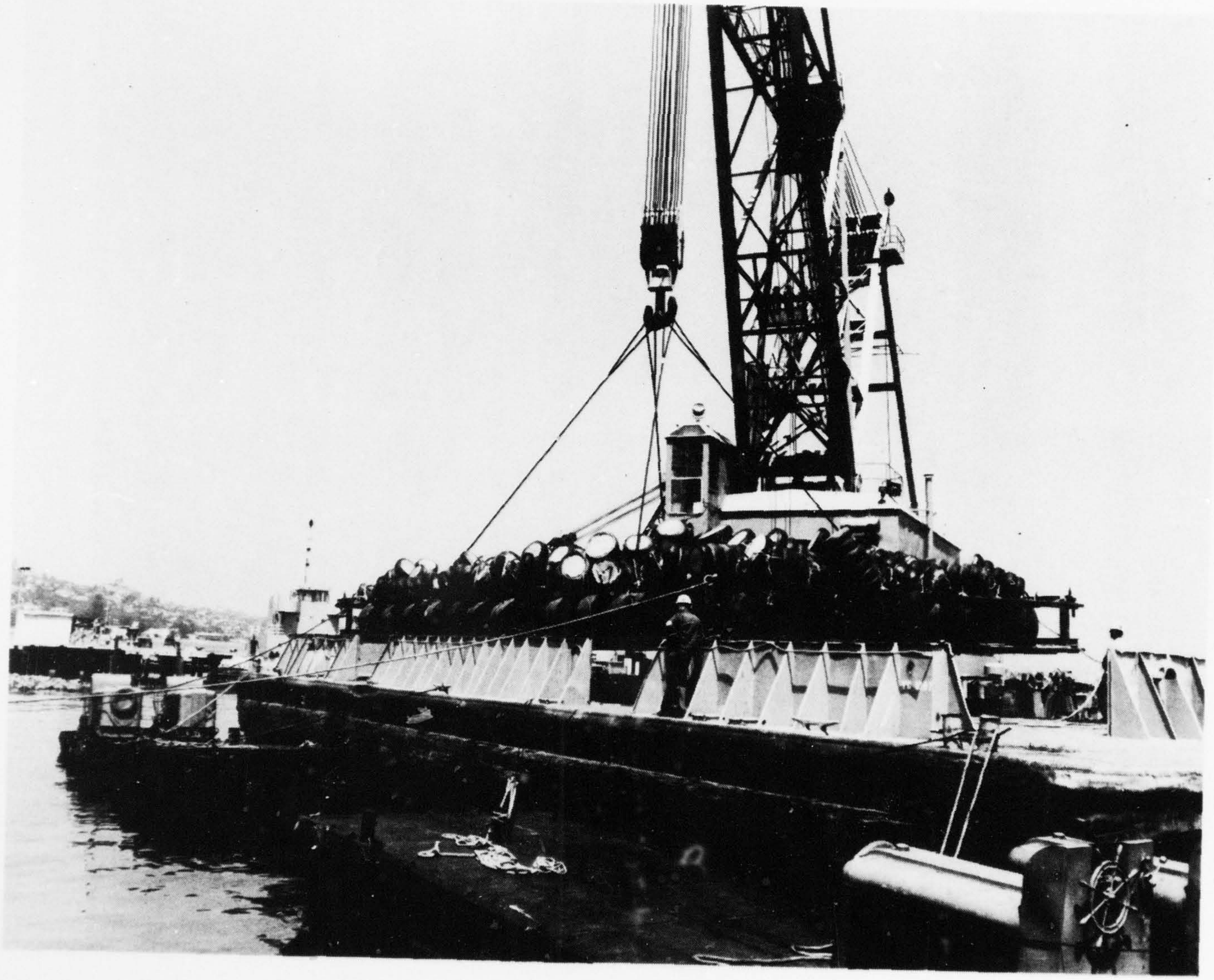

Figure 59. Launching Tethered Float Breakwater Module No. 1 using floating crane.

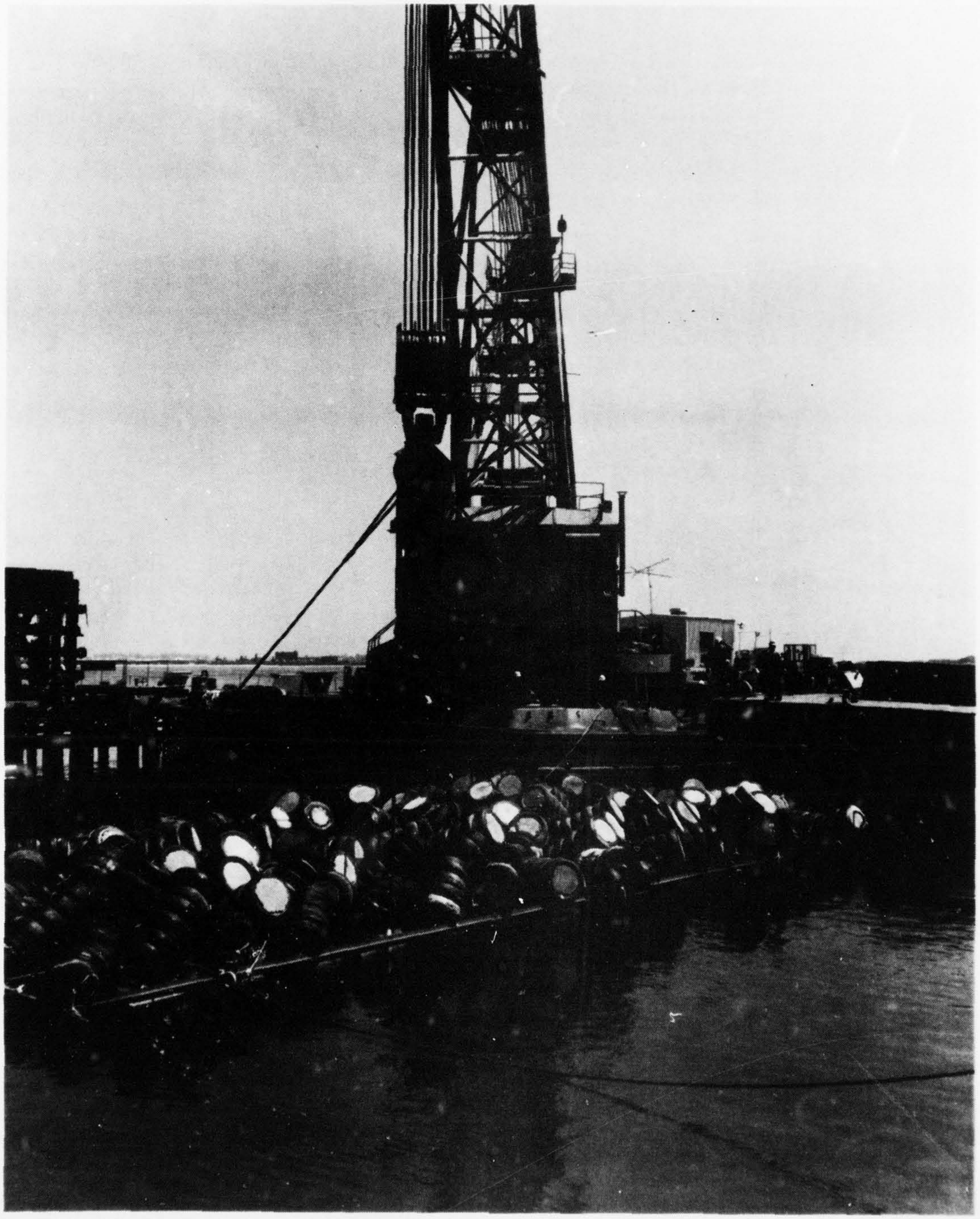

Figure 60. Positioning Module No. 1.

Figure 61. Final staging of both Tethered Float Breakwater modules.

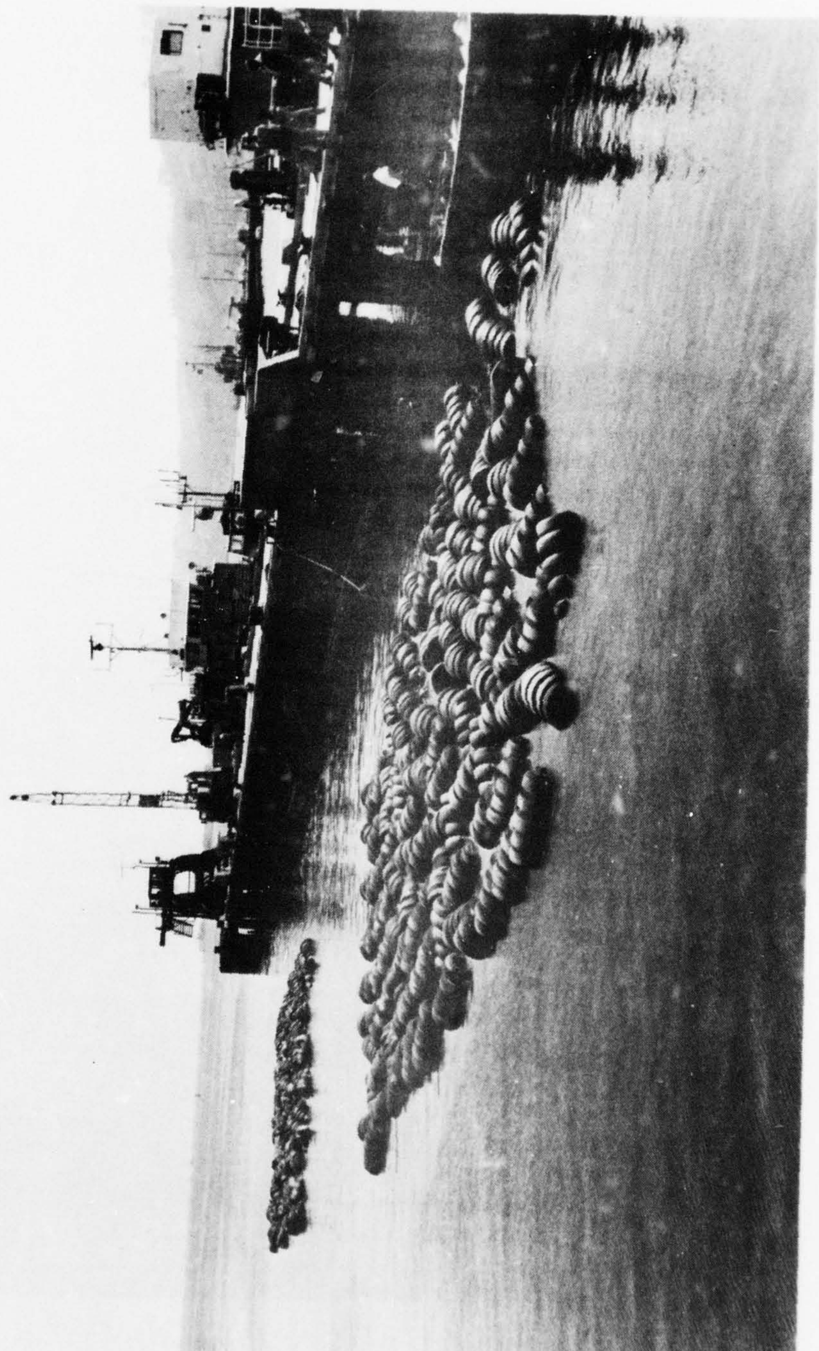

Figure 62. Overnight berthing of Tethered Float Breakwater modules.

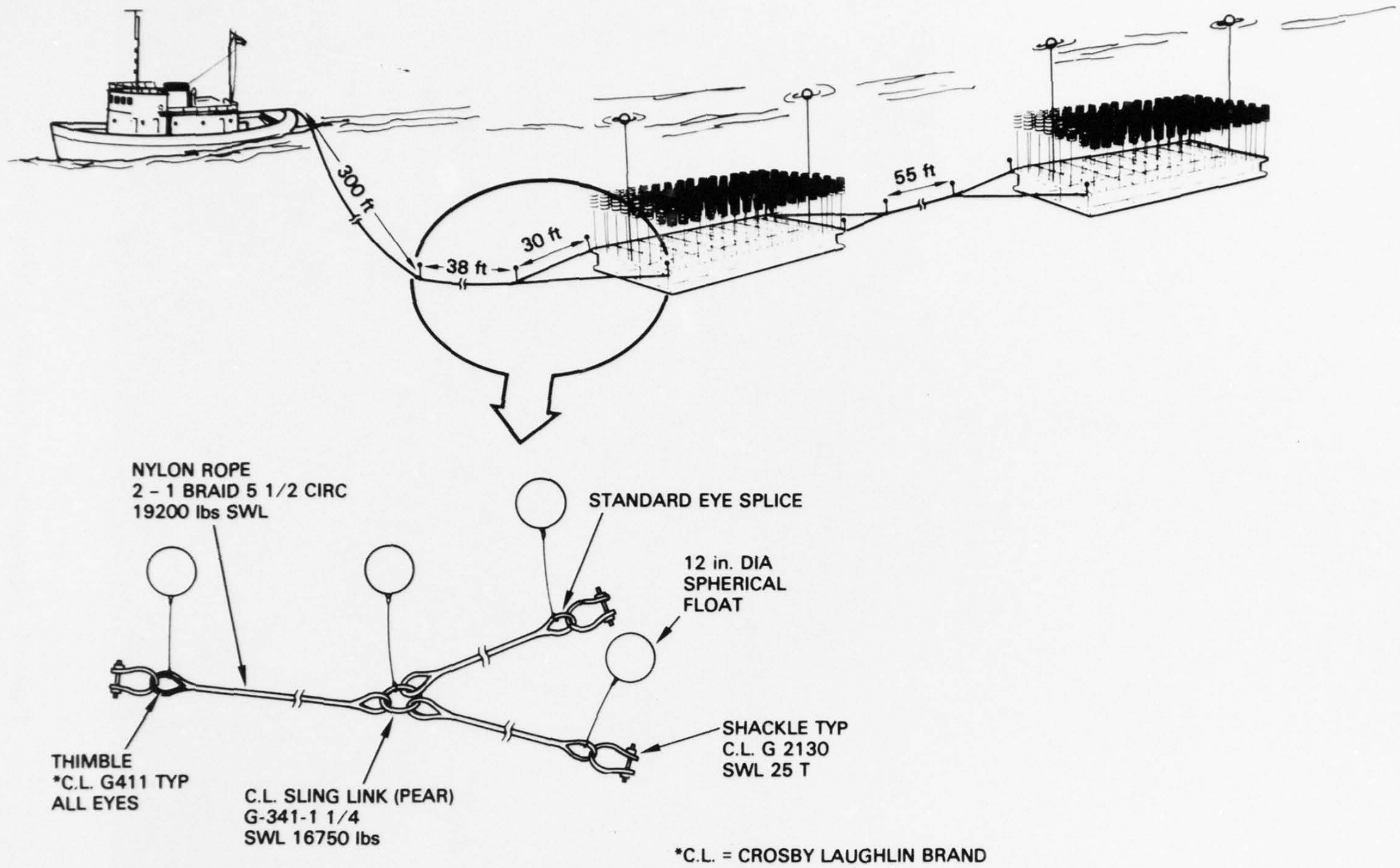

Figure 63. TFB tow bridles.

Figure 64. Tug preparing to get underway with Ocean Model.

Figure 65. Towing Ocean Model in San Diego Bay.

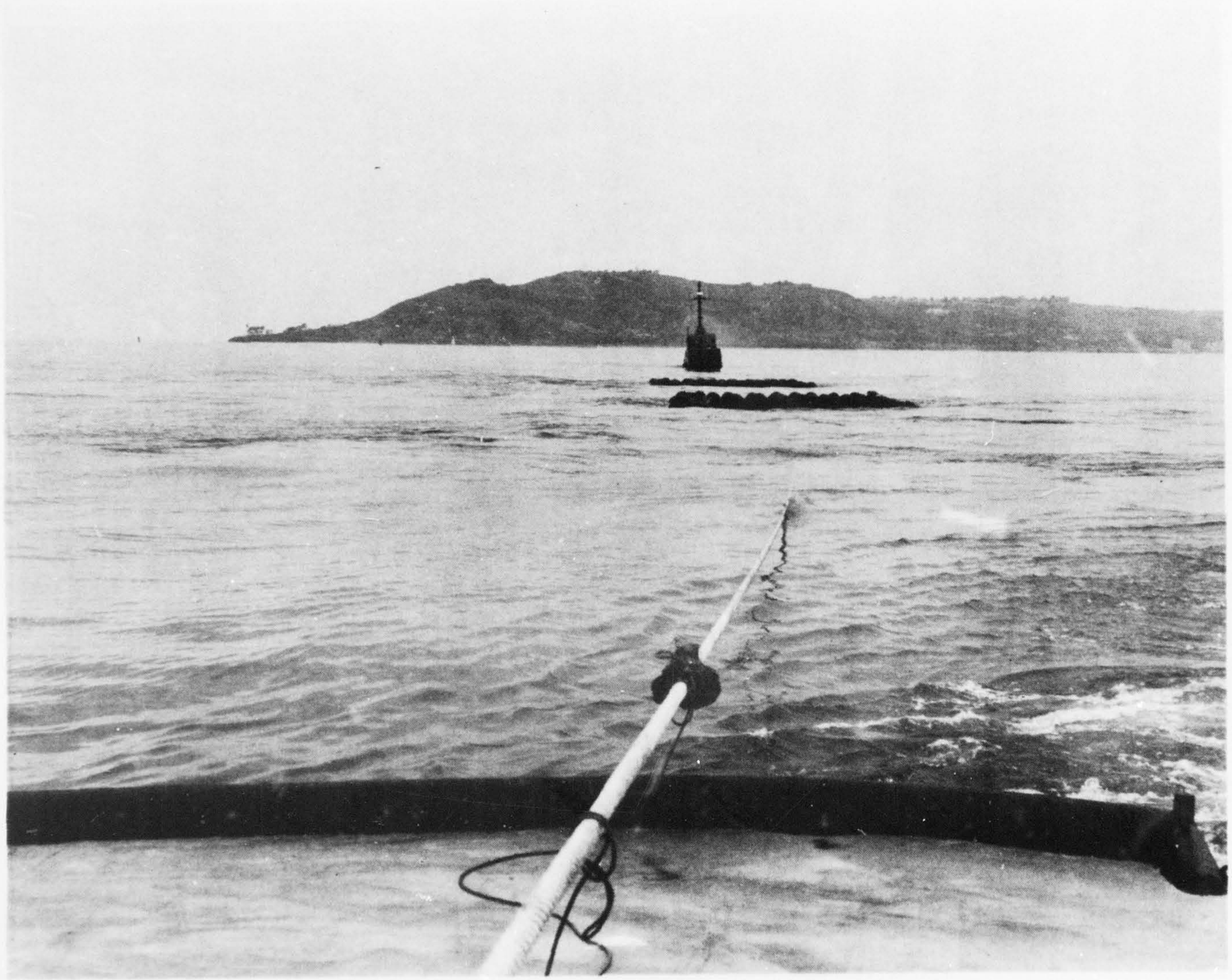

Figure 66   Rounding channel marker with TFB in tow.

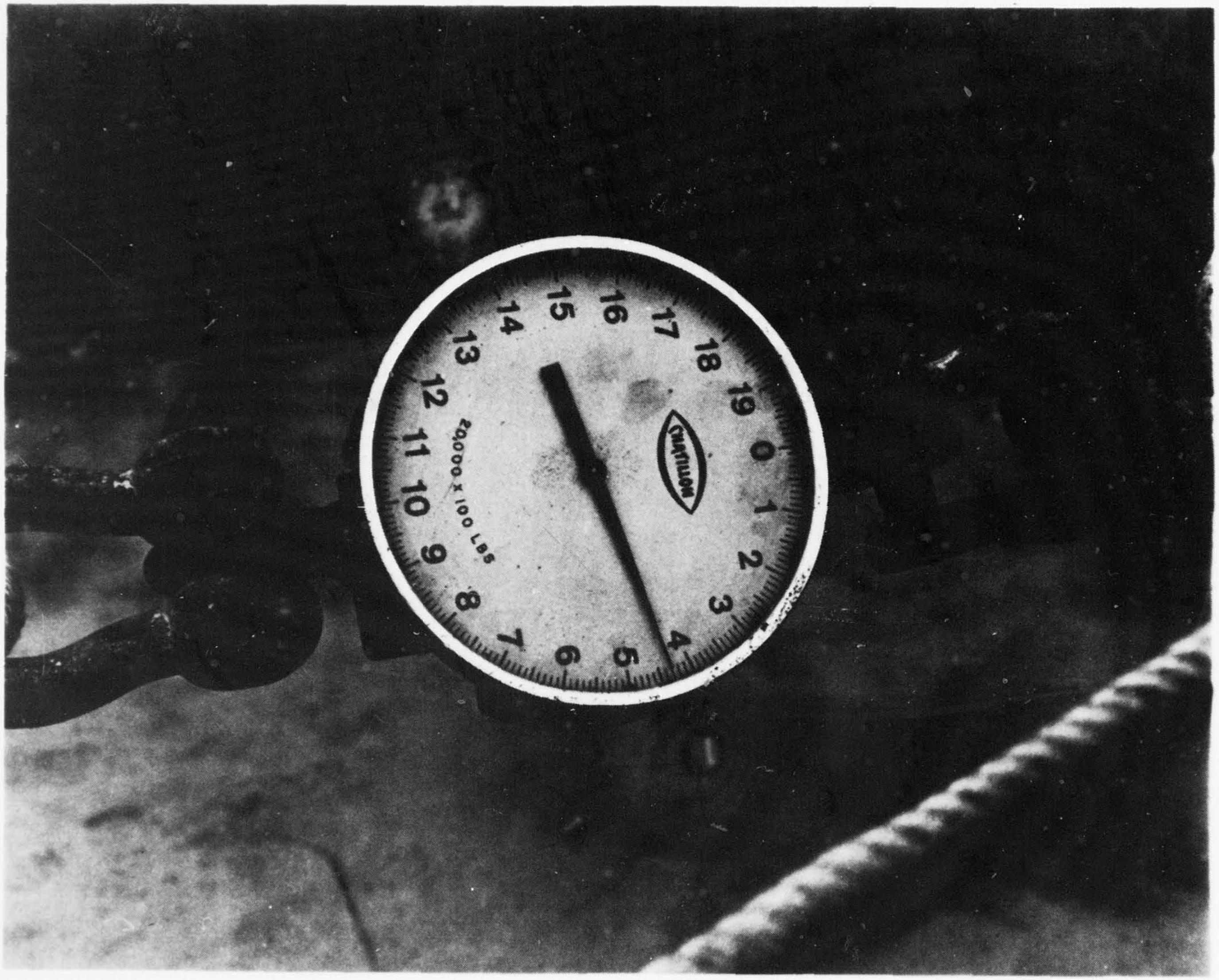

Figure 67. Dynomometer showing line tension at speed of 1.8 knots.

An average speed of three knots was then maintained in open ocean until the test site was reached (Figure 68).

At 1120 hours the tug arrived at the operation area staging-buoy, 450 yards west of the test site. The workboat attached a trailing line from Module No. 2 to the staging moor (Figure 69). The tug slacked the tow line and let both modules stream downcurrent. The breakwater assemblies were rigged for a three-point moor at the installation site and for flooding of ballast tanks. The three interconnect hoses (Figure 70) were installed on each unit. The tugboat maneuvered Module No. 1 clockwise to bring both units side by side (Figures 71 and 72), so that three interconnect-chains 10 feet in length could be shackled between the modules. The inter-module tow bridle was removed, and the forward bridle repositioned on the port side of Module No. 2. The tug was also repositioned in preparation for towing both units to the actual installation site (Figure 73).

Module No. 1, which had been launched from the assembly barge on the day prior to installation, was exposed to a negative pressure differential of 5-to-6 PSI, since the ballast tanks were sealed with only one atmosphere of pressure. (Module No. 2 was already in the water; when it was resurfaced, the internal tank pressure was equalized during the deballasting process). When the protective caps on the flood side of each of the three tanks were removed (prior to attaching the interconnect hoses) the pressure differential produced a substantial inrush of water. The module started to sink slowly. After the hoses were attached, however, the ballast tanks should have again been sealed. This was not the case. All three female hose fittings leaked substantially. The reason for the leaks was dislodged flange gaskets. Since the unit continued to sink, it was necessary to moor the diving boat to the ballast frame, attach an air hose from the onboard compressor to the starboard outside ballast tank, and resurface the module (Figure 74). Once this was accomplished, the normal operation was resumed.

During the afternoon, a westerly wind gradually increased to approximately 12 knots, producing a two-foot surface chop. This condition prevailed throughout the remainder of the installation effort.

The tug maneuvered to remove slack from the towing bridle (Figure 75), then the mooring line to the staging buoy was cast off. Both TFB assemblies, separated only by the ten foot lengths of chain, were towed to the test site and placed in a three-point moor (Figure 76). The longitudinal axis of the ballast tanks was oriented perpendicular to shore. The modules were flooded in sequence through a flood port on the left tank and a vent hose to the surface on the right tank (Figures 77, 78 and 79). The tug maintained a strain on the southern mooring leg to keep the breakwater in proper position and prevent the second module from shifting over the first. Actual time required to flood each ballast (four tanks per module) was 20 minutes.

All hoses, mooring lines, tow bridle, and miscellaneous hardware were removed from the breakwater. A polypropylene line was installed between the end of Module No. 1 and the seaward mooring buoy. Changes in line tension served as an indicator in monitoring any shoreward excursions of the TFB modules.

Appendix O is a detailed sequence of operations for the TFB Ocean Model installation at Imperial Beach.

Figure 68. Open ocean tow of TFB Ocean Model.

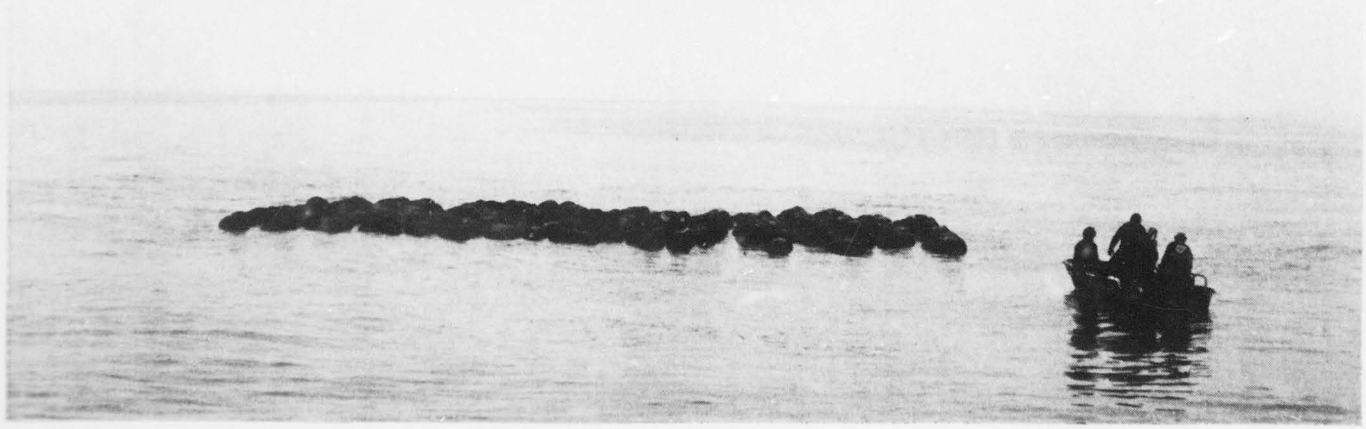

Figure 69. Mooring Module No. 2 to staging buoy.

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ENGINEERING REPORT: TETHERED FLOAT BREAKWATER NEAR-SHORE OCEAN --ETC(U)
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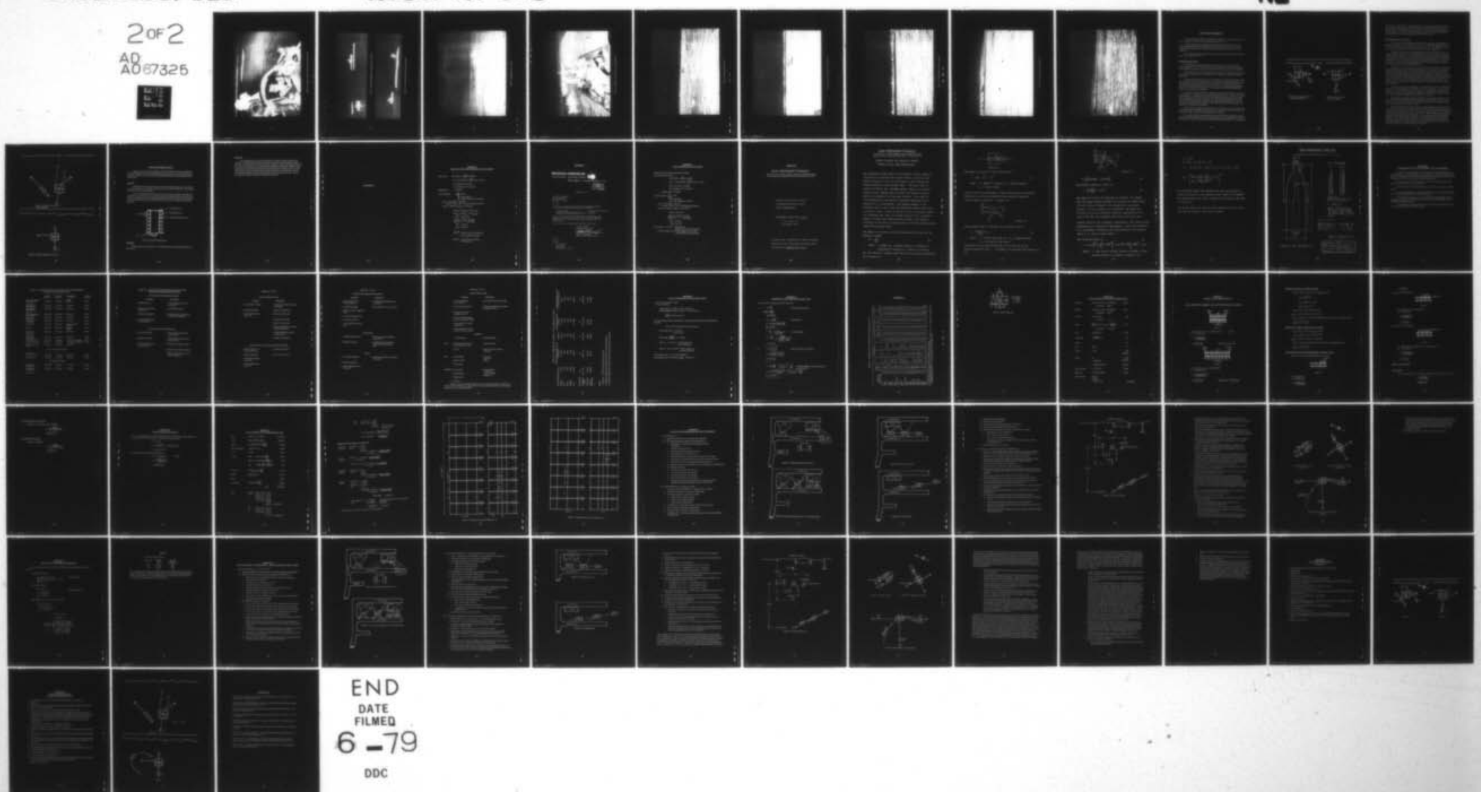

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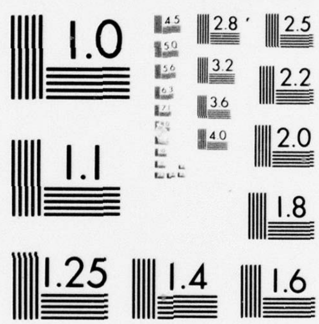

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 70. Preparing to install interconnect hoses on ballast tanks.

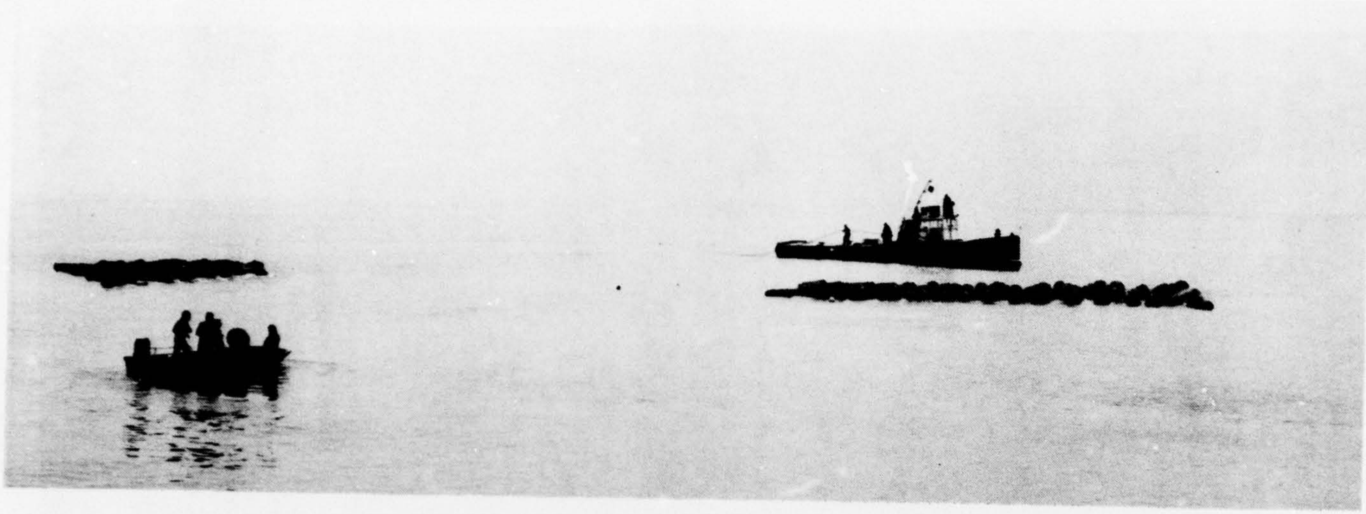

Figure 71. Repositioning Module No. 1 alongside second module.

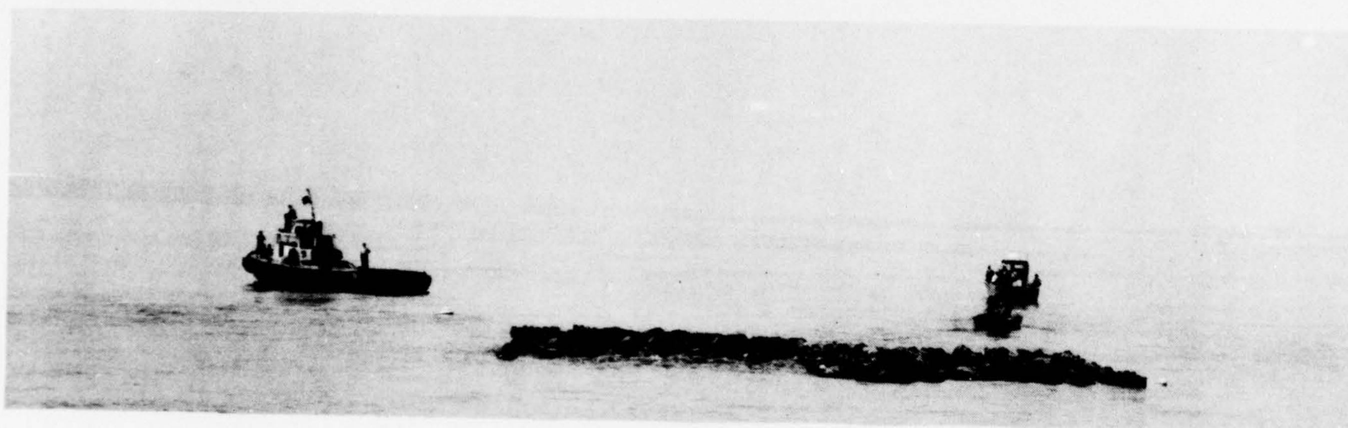

Figure 72. Interconnecting both Ocean Model assemblies.

Figure 73. Beginning of tow to test site.

Figure 74. Preparing to attach airline to resurface Module No. 1.

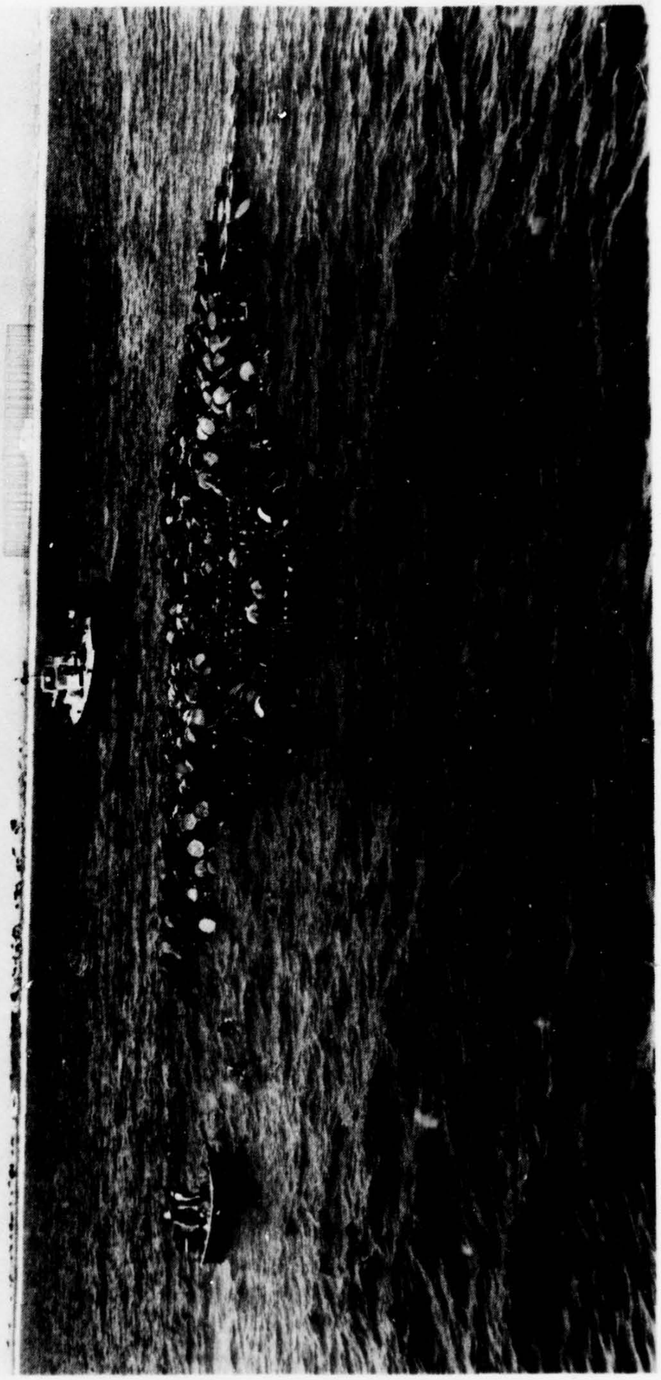

Figure 75. Ocean Model ready for tow.

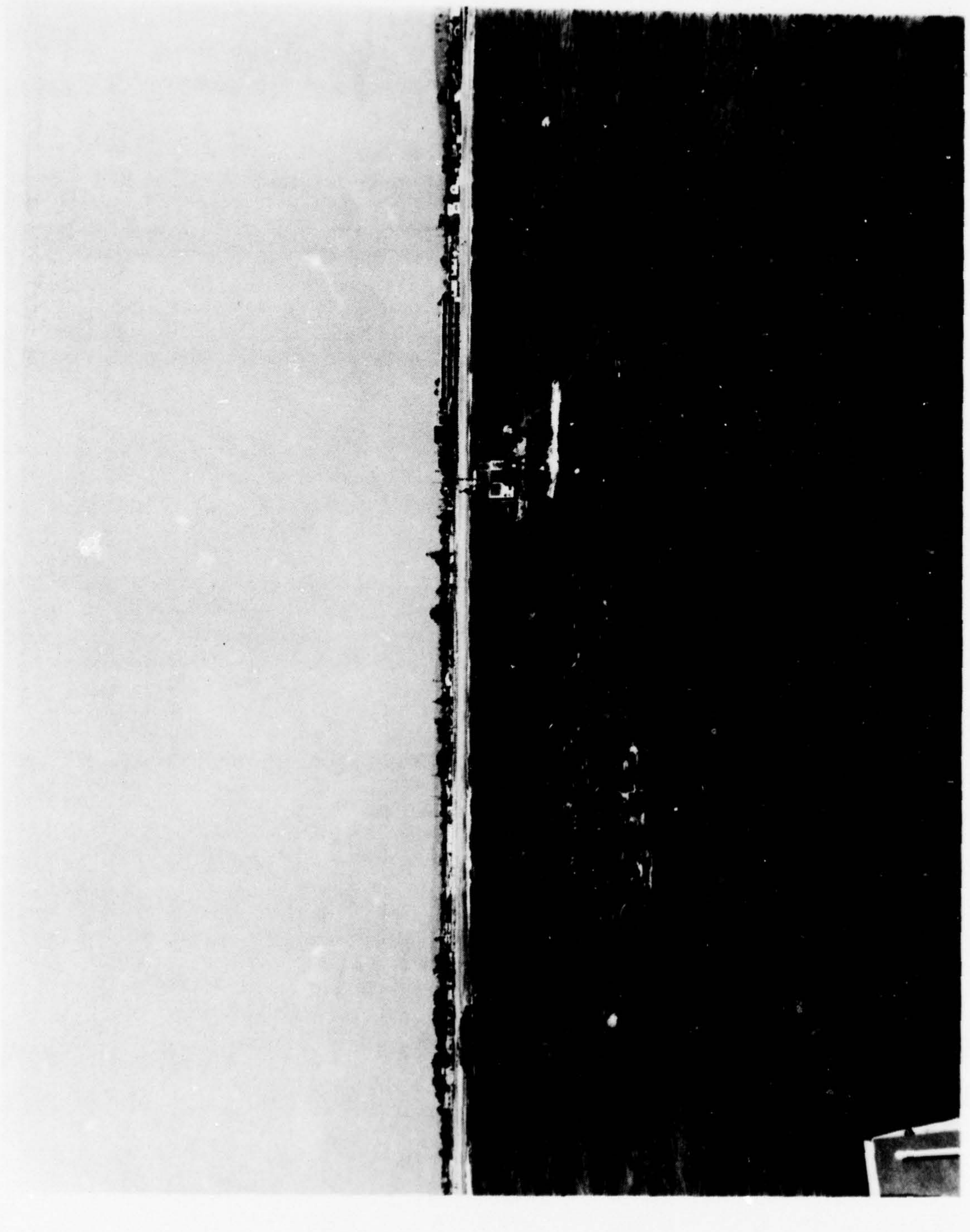

Figure 76. Mooring Ocean Model at installation site.

Figure 77. Flooding ballast tanks on first assembly.

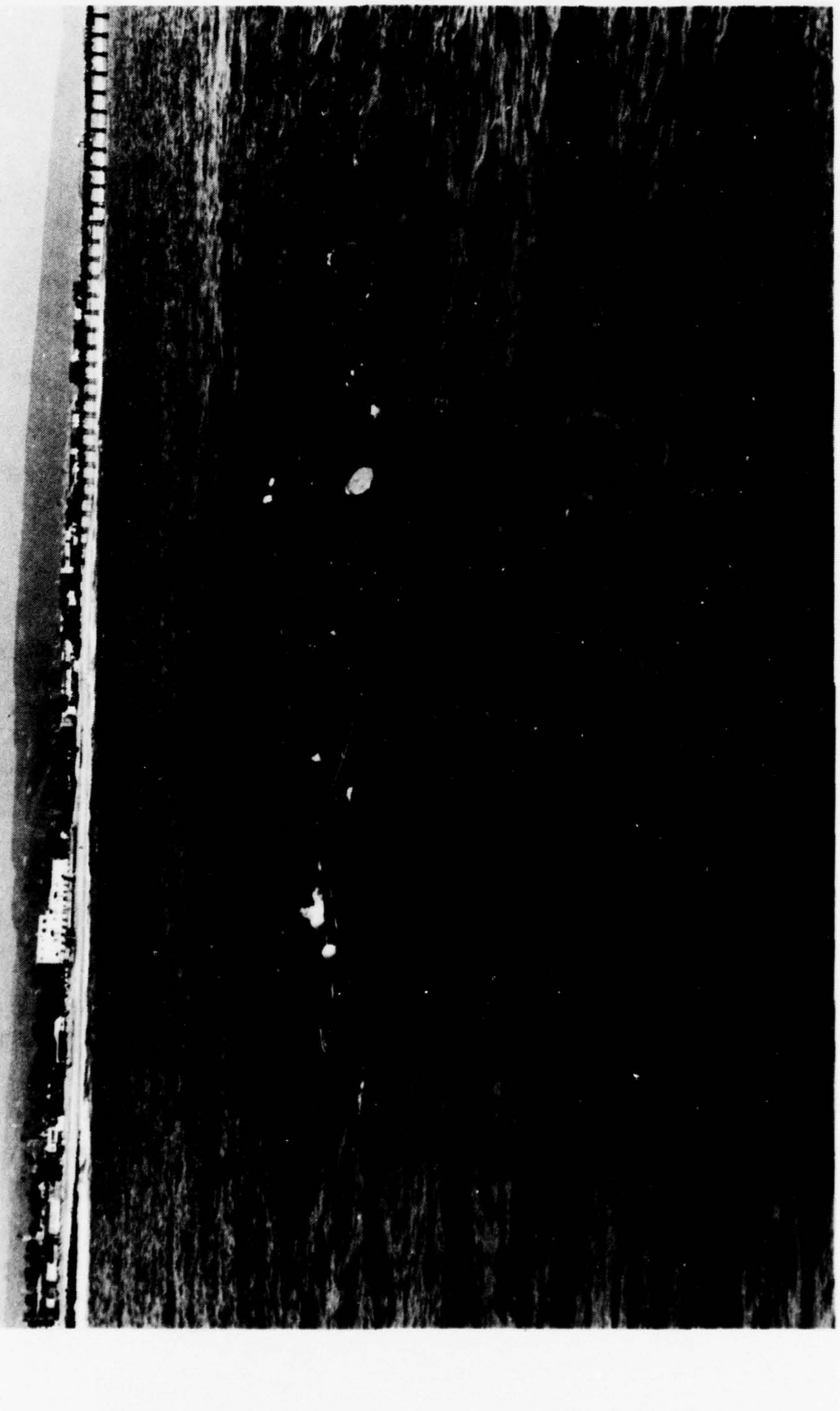

Figure 78. Starting to ballast down Module No. 2.

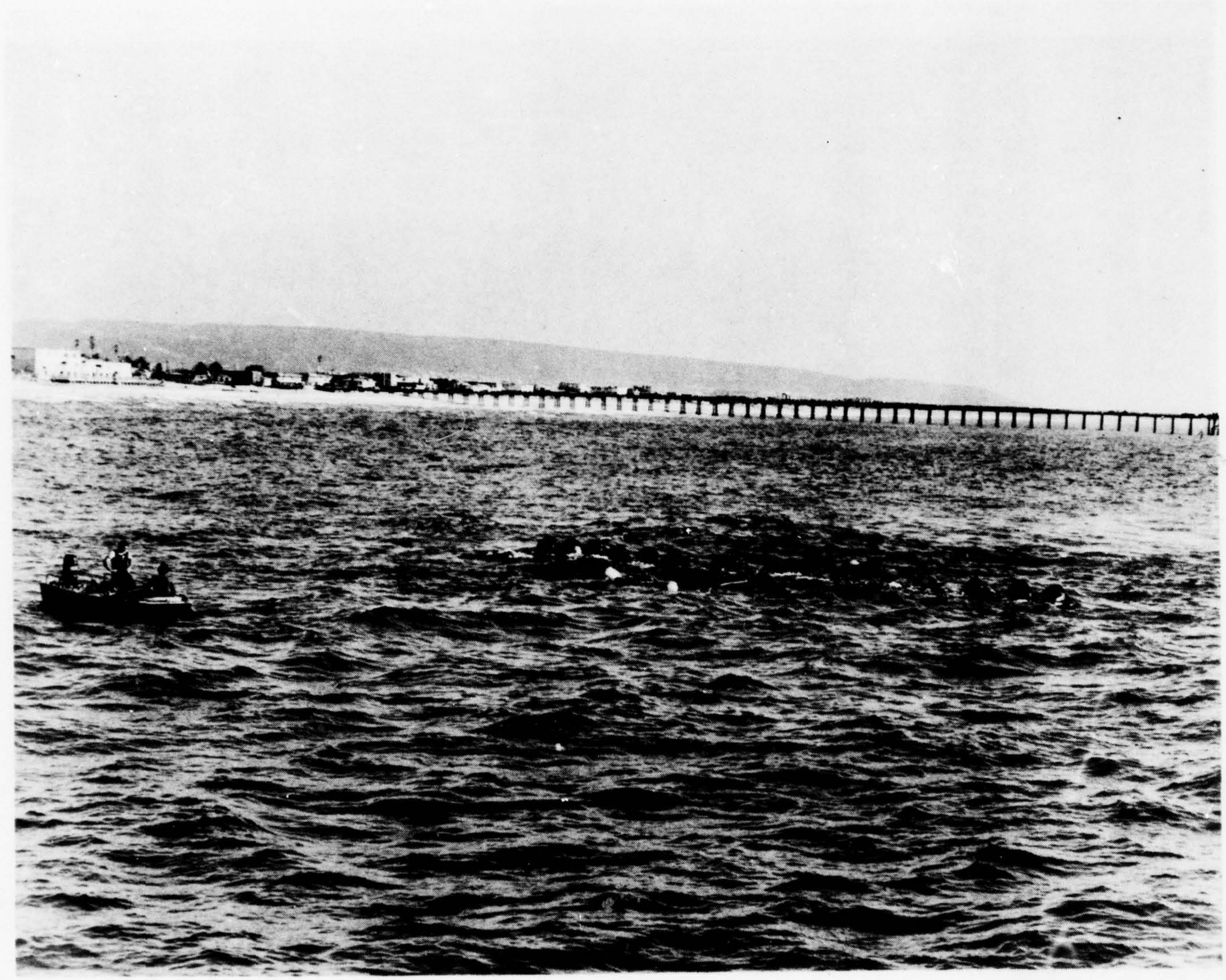

Figure 79. Installation of TFB Ocean Model is completed as final row of floats submerges.

RELOCATION EXPERIMENTS

Following initial installation of the TFB Ocean Model, two relocation experiments were conducted to evaluate system portability in the open ocean.

The first experiment, an in-place 90° rotation, increased operational experience with the deballasting procedure, and allowed for evaluation of the scouring and burial tendency of the modules with the ballast tanks oriented parallel to the beach versus perpendicular.

The second relocation experiment included recovery of both modules, and a broadside tow to a shallower test site.

90 DEGREE ROTATION

The TFB Ocean Model was deballasted and relocated on 14 June 1978, at the Imperial Beach Test Site. The breakwater was rotated 90 degrees so that the ballast tanks became parallel to the beach. Relocation procedures listed in Appendix P were followed.

Upon arrival at the test site the diving boat was placed in a two-point moor between the northern and seaward buoys. Mooring lines were attached to each ballast as shown in Figure 80.

Both units were prepared for recovery. All pipe caps and plugs were removed; four inch interconnect hoses were installed; the one-inch polypro line joining Module No. 1 and the seaward buoy was disconnected and secured to the moor. Both two-inch vent hoses were installed and buoyed off at the surface. All valves were opened. The tow bridle was shackled to the south side of Module No. 2, then passed to the tug PT&S CORONADO (same vessel as used for the installation).

An air line from the low-pressure compressor on board the diving boat was connected to Module No. 2 at 0905 hours to start the deballasting operation. The first row of floats broke the surface at 0930 hours. The ballast assembly surfaced unevenly due to trapped water sloshing back and forth in the tanks. This condition was aggravated by the size of the swells and the orientation of the ballast tanks (perpendicular to the beach). All four tanks were vented through the standpipe on the seaward end to stabilize the module. Deballasting was completed at 1020 hours.

The air hose was transferred to Module No. 1 at 1029 hours. The same problem was encountered with the assembly surfacing on an incline. Separately venting two of the tanks leveled the module. Deballasting was completed at 1130 hours.

Once both modules were completely afloat, the tug maneuvered them into the new position with ballast tanks parallel to the beach (Figure 81). The tug maintained a strain on the tow line to keep the two modules separated during flooding. Module No. 1 was flooded

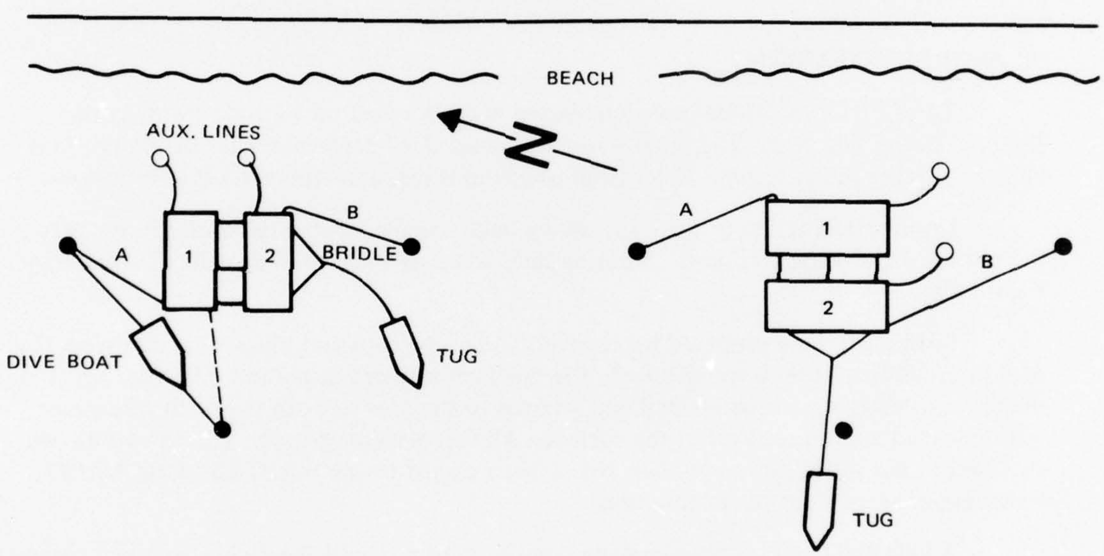

Figure 80. Mooring arrangement for relocation experiment.

Figure 81. Position of Ocean Model after rotation.

first, then No. 2. Module No. 1 suffered a broken one-half inch valve while on the surface. This caused the tanks to take on water prematurely. Since the assembly was already in proper position, no real difficulty was encountered. The tow bridle was disconnected and the tug released at 1315 hours. All lines and hoses were removed. Dust caps and plugs were replaced on the four-inch plumbing, and all valves were closed.

TRANSFER TO NEW TEST SITE

On 2 August 1978, the TFB Ocean Model was moved from the original Imperial Beach site (32°35′15″N, 117°08′10″W) to a new test site 2,400 yards north (32°36′25″N, 117°08′11″W). Water depth is 20 feet at mean lower low water. The TFB is located 250 yards offshore. Procedures for the transfer operation are given in Appendix Q.

The MIKE-8 was used as an operations platform because the diving boat was not available. Upon reaching the test site the MIKE-8 was placed in a two-point moor between the northern and seaward buoys. A single mooring line was attached between the leeward ballast (Module No. 1) and the southern surface float, as shown in figure 82. The TFB was prepared for recovery by removing the pipe caps and plugs, installing the four inch interconnect hoses, and making a general inspection. The tow bridle was shackled to Module No. 2, then passed to the tug (PTS CORONADO).

Although the four ballast tanks on each module were interconnected for sequential deballasting, this was not done. The four inch tank valves remained closed. An optional procedure was followed that would allow the assembly to be surfaced in a level attitude. Tanks were deballasted separately, by connecting the air supply to the standpipe on one end of the cylinder and venting through the pipe at the opposite end. The original intention was to blow only three of the four tanks on each unit. This would increase the load on the tethers, and prevent some of the chaffing that occurred during previous exercises. The buoyancy of three tanks, however, was not sufficient to raise the modules; the fourth was also deballasted.

The air line was connected to Module No. 2 at 0844 hours. Tanks were deballasted in this order: A, D (outboard), C, B (inboard). Each took 16 minutes to vent completely. The first row of floats broke the surface at 1021 hours. Deballasting was completed at 1033 hours. The air hose was transferred to ballast No. 1 at 1044 hours. Again, the tanks were blown separately. Deballasting was completed at 1216 hours.

By dewatering the ballast tanks as outlined above, the modules surfaced in a relatively level condition. During past relocation experiments when tanks were blown sequentially, there was a tendency for the frame to break the surface and a much greater opportunity for tethers to become chaffed or fouled.

With both assemblies completely afloat, the CORONADO towed the modules (still interconnected by three pieces of chain) to the new test site. Approximately one hour was required to travel 1.2N miles. The units were moored as shown in Figure 83. Both two-inch vent hoses were attached and buoyed off at the surface. The four-inch valves were opened and four inch pipe cap removed on Module No. 1 to sequentially flood the ballast tanks; Module No. 2 was flooded in the same manner. The tug maintained a constant strain on the towline to keep the assemblies separated. The tow bridle was removed and the tug released at 1440 hours. Vent hose and four-inch interconnect hoses were recovered. All valves were closed and dust caps and plugs were replaced.

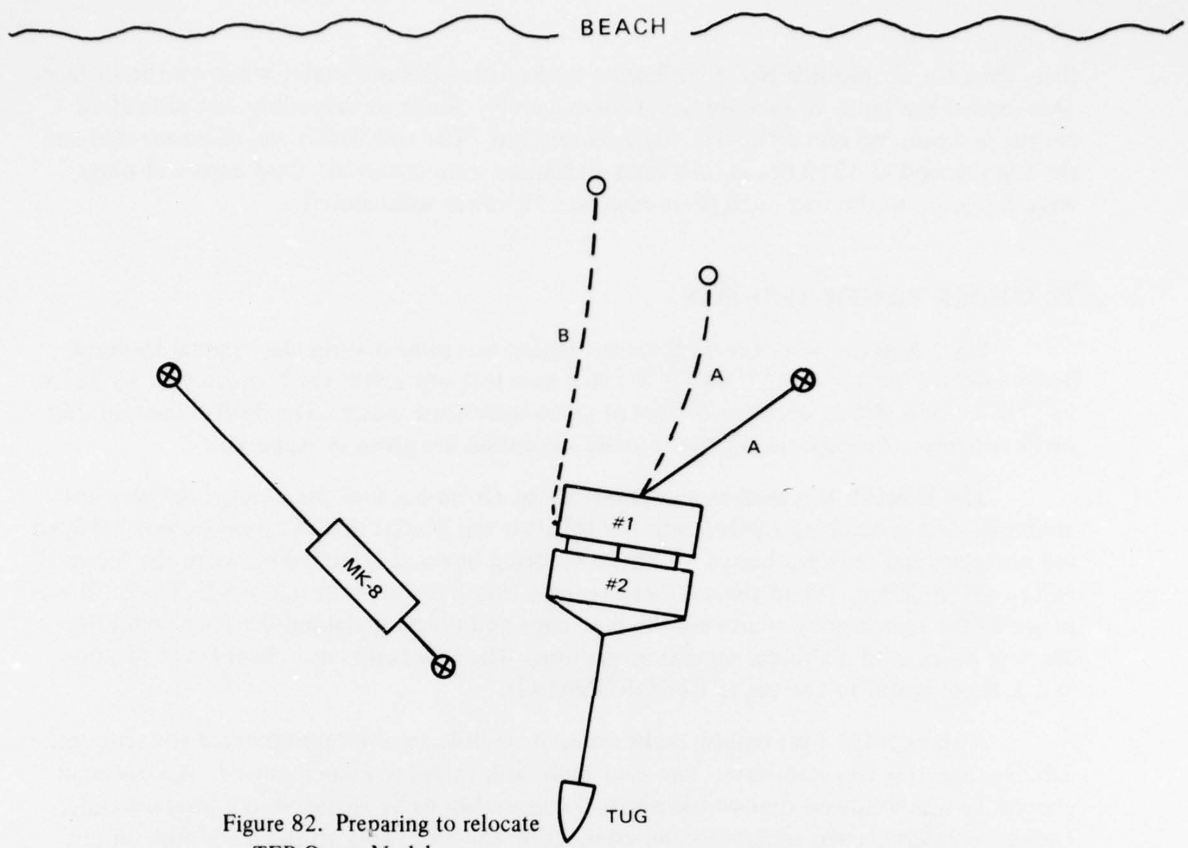

Figure 82. Preparing to relocate TFB Ocean Model.

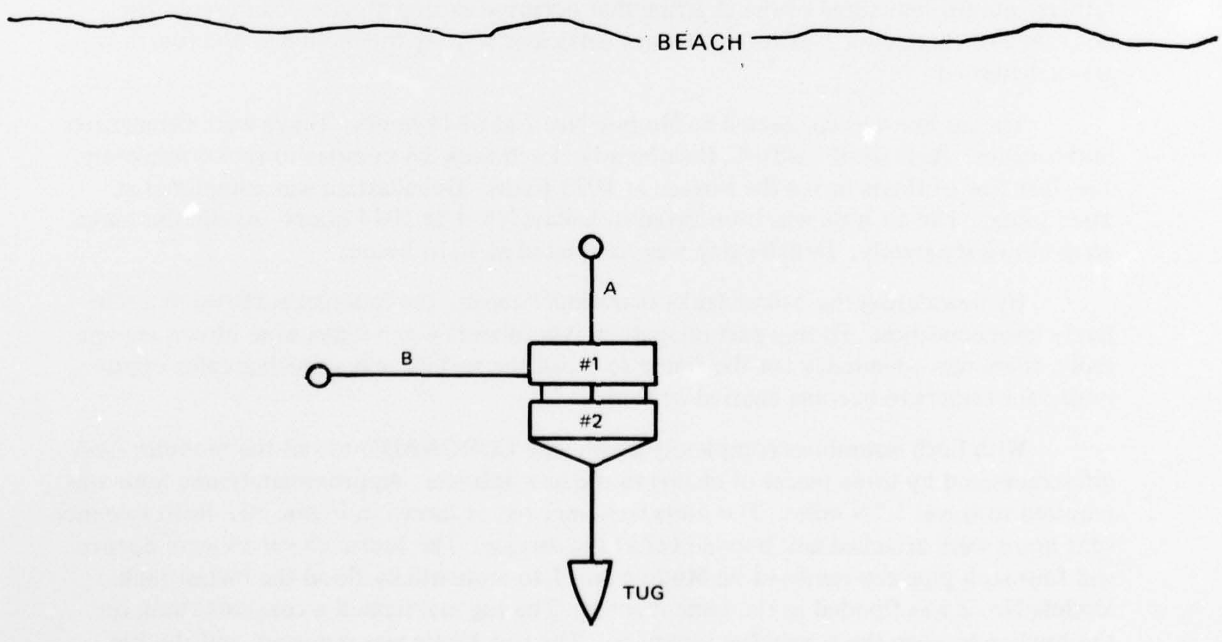

Figure 83. Mooring arrangement at new test site.

DESIGN RECOMMENDATIONS

During the interim test and evaluation period at NOSC and the actual installation off Imperial Beach, the TFB Ocean Model was evaluated in terms of hardware performance. This study resulted in several recommended design modifications for future shallow-water TFB systems.

FLOATS

Although the tire floats performed as anticipated, fabrication was very time consuming. All tires had to be individually weighed and sorted to achieve uniformity. Polyurethane was poured into each tire separately.

It is recommended that future floats be constructed from a molded water-tight core surrounded by a group of tires. The bottom of the core would incorporate a bail for tether attachment; density of the float could be controlled by varying the amount of core material. The tires would entrap water, increasing the mass of the system. A sample is illustrated in Figure 84.

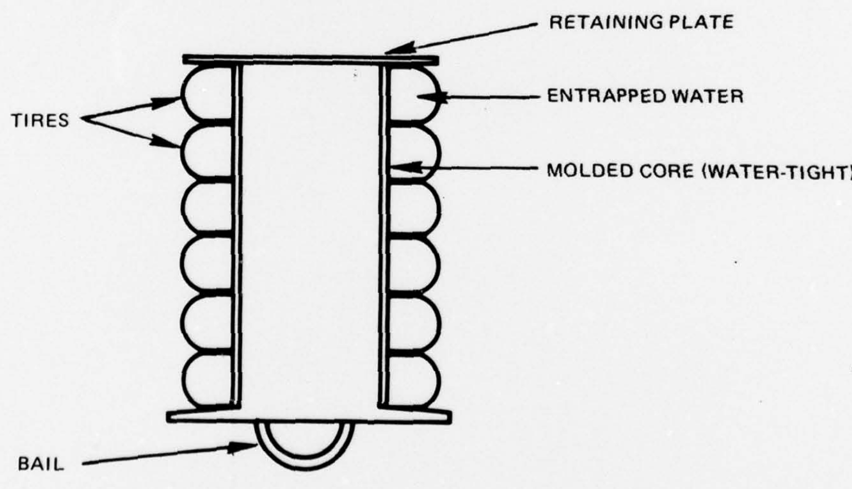

Figure 84. Proposed Ocean Model float.

TETHERS

Initial design was most satisfactory. No problems were encountered with tethers or terminations.

BALLAST

The deballasting system should be modified to provide for better control of the assembly. An odd number of tanks would allow the module to be deballasted symmetrically. The one half-inch valves on the ends of the cylinders are subject to damage, and should be removed. Since tanks can be separately vented through the standpipes, individual valves at this location would provide for easier operations (Pipe caps are currently used). A manifold located at each end of the assembly would be beneficial. The ballast tanks could be interconnected using two-inch pipe, with a separate valve installed on each one. A single air connection would be used on the manifold for simplicity.

APPENDICES

APPENDIX A
ORIGINAL TIRE FLOAT MATERIAL CALCULATIONS

For 5 tires = $\mathrm{Vol} = \pi R^2 L - 5\left(\frac{bh}{2}\right)\pi\left(R - \frac{h}{3}\right) 2$

$$V = \pi (12.5)^2 (50) - 5\frac{4(3)}{2}\pi (12.5 - 3/3)\ 2$$

$$V = 24{,}543.69 - 2{,}167.70$$

$$V = 22{,}375.99 \text{ in}^3 = 12.95 \text{ ft}^3$$

Displacement = 828.8 lb

For 0.56 density $= \frac{\mathrm{Wt}}{\mathrm{Displ}} = 0.56$

$\mathrm{Wt} = 0.56\ (828.8)$

$\mathrm{Wt} = 464.13$ lb/364.67 lb buoyancy

(Tire = 25 lbs; Rebar = 26.5 lbs)

464.13 - 5 (25) - 26.5 = 312.63 lb foam & concrete

(Foam = 2 lbs/ft^3; Concrete = 137 lb/ft^3)

$$\mathrm{Vol}_{total} = \mathrm{Vol}_{foam} + \mathrm{Vol}_{concrete}$$

$$\mathrm{Wt}_{total} = \mathrm{Wt}_{foam} + \mathrm{Wt}_{concrete}$$

$$\begin{aligned} 12.95 &= \mathrm{Vol}_f + \mathrm{Vol}_c \\ 312.63 &= 2\ \mathrm{Vol}_f + 137\ \mathrm{Vol}_c \\ \hline 286.73 &= 135\ \mathrm{Vol}_c \\ \mathrm{Vol}_c &= 2.12 \text{ ft}^3 \\ \mathrm{Vol}_f &= 10.83 \text{ ft}^3 \end{aligned}$$

$\frac{2.12 \text{ ft}^3}{2} = 1.06$ ft^3 concrete on each end

= 3.73 in. thick on each end

1.06 ft^3 = 145.22 lb dry (each end)

159.74 lb wet

APPENDIX B

REICHHOLD CHEMICALS, INC.

Creative Chemistry . . . Your Partner in Progress

World Headquarters • RCI BUILDING, WHITE PLAINS, N. Y. 10603

ADDRESS REPLY TO
107 SOUTH MOTOR AVENUE
P.O. BOX 22
AZUSA, CALIFORNIA 91702

PHONE: (213) { 283-4123 / 334-4974

January 30, 1978

Mr. James Clinkenbeard
Naval Ocean Systems
2337 Palermo Drive
San Diego CA 92106

Dear Jim:

I have received a sample from Popoff Foam to run physical properties on foam core. The results of our testing are as follows:

In Place Density	- 3.22 pounds per cubic foot.
Compressive Strength-Parallel to Rise	- 43 P.S.I.
Compressive Strength-Perpendicular to Rise	- 34 P.S.I.

As you will observe from the enclosed sample, cell structure is very uniformed with an excellent outer skin. It is our opinion that the physical properties tested are ample for your application with a 10% safety margin.

Please contact me for any additional information you may need.

Yours very truly,
REICHHOLD CHEMICALS, INC.

Milton D. Cunningham
Milton D. Cunningham
Technical Sales Representative

MDC:slg

Enclosure

cc: Mr. Jack Popoff
Popoff Foam
346 E. Myrtle
San Carlos CA 92069

APPENDIX C
FINAL TIRE FLOAT CALCULATIONS

Sample tires vary in diameter from 24–29 inches.

For 6 tires @ 26½ in. dia. =

$$\text{Vol} = \pi R^2 L - 6\left(\frac{bh}{2}\right)\pi\left(R - \frac{h}{3}\right)2$$

$$\text{Vol} = \pi(13.25)^2(50) - 6\,\frac{4(3)}{2}\,\pi(13.25 - 3/3)\,2$$

$$\text{Vol} = 27{,}577.29 - 2{,}770.88$$

$$\text{Vol} = 24{,}806.41\ \text{in}^3 = 14.36\ \text{ft}^3$$

Displacement = 919.04 lb

For 0.56 density = $\dfrac{\text{Wt}}{\text{Displ}} = 0.56$

$$\text{Wt} = 0.56\,(919)$$

$$\text{Wt} = 514.64\ \text{lb/Buoy} = 404.4\ \text{lb}$$

(Tire = 25 lb; Rebar = 26.5 lb)

514.64 - 6 (25) - 26.5 = 338.14 lb foam & concrete

(Foam = 2.8 lbs/ft^3; Concrete = 137 lb/ft^3)

$$14.36 = \text{Vol}_f + \text{Vol}_c$$

$$\underline{338.14 = 2.8\ \text{Vol}_f + 137\ \text{Vol}_c}$$

$$297.93 = 134.2\ \text{Vol}_c$$

$$\text{Vol}_c = 2.22\ \text{ft}^3$$

$$\text{Vol}_f = 12.14\ \text{ft}^3$$

For concrete = 2.22 ft^3 = 304.14 lb dry

334.55 lb wet (167.3 lbs each end)

2.22 ft^3 = 3836.16 in^3 = 6.96 in thick for a 26½ in dia.

= 3.48 in thick on top and bottom

APPENDIX D

Lane Instrument Company

1548 FAYETTE ST., EL CAJON, CA 92020 • PHONE 714-448-8783 OR 448-6924

DESIGN OF BOOTS FOR CONTROL
OF BENDING RADIUS AT WIRE
ROPE TERMINATIONS.

LABORATORY REPORT NO. 1057

N. W. Lane, Jr.

16 August 1976

Design study conducted for Naval Undersea Center by Lane Instrument Company under Contract No. N66001-76-M-V163

Lane Instrument Company
1548 FAYETTE ST., EL CAJON, CA 92020 • PHONE 714-448-8783 OR 448-6924

DESIGN OF BOOTS FOR CONTROL OF BENDING RADIUS AT WIRE ROPE TERMINATIONS

The objective of this report is to present a simple approach to design of a variable beam sleeve (boot) to restrict the bending radius of a line or rope under a known tension and flexing through a known maximum angle. The input data required for design are: Maximum bending radius, line radius, tensile force, maximum angle of bend, and tangent flexural modulus of elasticity of the boot material. The output of the calculation is the exterior envelope dimensions as described by x, y coordinates. The tangent modulus of the elastomer used in this study was determined rather than using literature values. Where literature values of flexural modulus for elastomers are used, the tangent modulus will be approximately 1.4 times the reported secant values. The flexural stiffness of the line is ignored since its effect would slightly reduce the envelope radii.

The shape of the boot is based on Bernoulli-Euler Law for the bending of beams.

$$M = \frac{EI}{R_o} \tag{1}$$

Where: $I = \int y^2 dA$, R_o = bending radius, E = modulus of elasticity in flexure, M = moment in the beam.

For the case of a variable beam boot with a circular crossection as in Figure D-1.

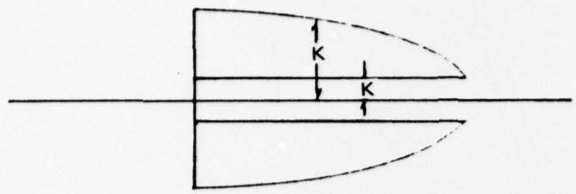

Figure D-1

The moment of inertia at each crossection is

$$I = \frac{4}{\pi} (r_1^4 - r_2^4) \tag{2}$$

Where: I = moment of inertia, r_1 = outside radius,

r_2 = inside radius.

Consider the boot surrounding a cable under tension and moving through an arc with the bending radius constant along the active length of the boot. (Figure D-2)

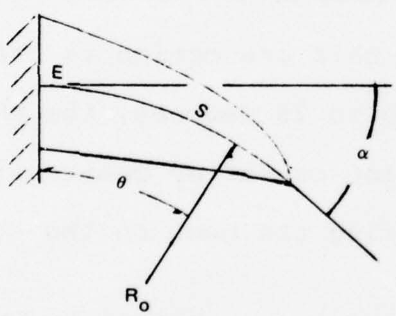

Figure D-2

The minimum length of the boot at the center line is

$$S = \frac{2 R_O \pi \alpha}{360} \tag{3}$$

Where: S = length along the arc. R_O = bending radius.

$\alpha = \measuredangle$ of bend of the tether.

The moment at the section defined at θ is the sum of the moments between θ and α. The moments are defined from Figure D-3, as:

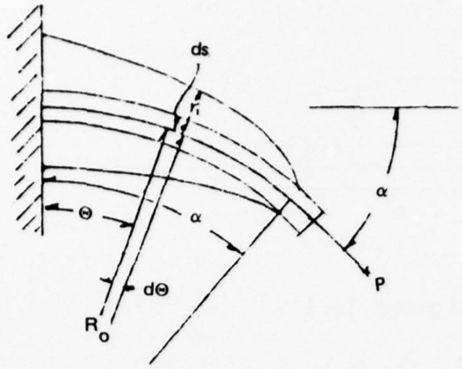

Figure D-3

$$M = \int_0^{\alpha} R_O P \sin\theta d\theta = -R_O P \cos\theta \Big|_0^{\alpha} \tag{4}$$

The exterior radius at θ then is:

$$r_1 = \left(\frac{\pi R_O M}{4E} + r_2{}^4 \right)^{1/4} \tag{5}$$

The shape of the boot as described by equation (5) assumes that the shape remains constant as a function of tether angle. For small angles 2 degrees, this assumption is practical. However, for large angles up to 25 degrees, the shape must be adjusted for the distortion caused by compressing of one side of the boot and elongating the boot on the other side.

Poisons ratio for the elastomers considered in this study varies predictably as a function of deformation. Tests were conducted on 3 elastomers to determine the relationship of the exterior radii at θ and at tether angle α.

The corrected radius is:

$$r = 2.05 \left[\frac{b^2 + (b^2 - 4ac)^{1/2}}{2a} \right]^{1/2} -0.55 \frac{b^2 + (b^2 - 4ac)^{1/2}}{2a} -0.09 \tag{6}$$

Where: r = the initial outside radius to produce a final outside radius of r_4 based on equation (5).

$$a = 6\ R_o^{\ 2}$$

$$b = r_4^{\ 2} - 12\ R_o^{\ 2}\ r_1^{\ 2} - r_2^{\ 2}$$

$$c = -\ (2\ R_o^{\ 2}\ r_4^{\ 4} + 4\ R_o^{\ 2}\ r_4^{\ 2}\ r_2^{\ 2} + R_o^{\ 2}\ r_2^{\ 4} - 6\ r_2^{\ 4}$$

$$r_4 = \left[\frac{R_o \quad (r_1^{\ 2} - r_2^{\ 2})}{R_o - \left(\frac{r_1^{\ 2} - r_1^{\ 2}}{2}\right)^{\frac{1}{2}}} + r_2^{\ 2} \right]^{\frac{1}{2}}$$

The corrected radius was computed for stations located in integral degrees (θ) with maximum tether angle of 25 degrees. The computations were used to establish the shape of the boot in figure D-4.

The inside radii were defined by the dimensions of the wire rope and the shank of the swaged fitting.

Lane Instrument Company

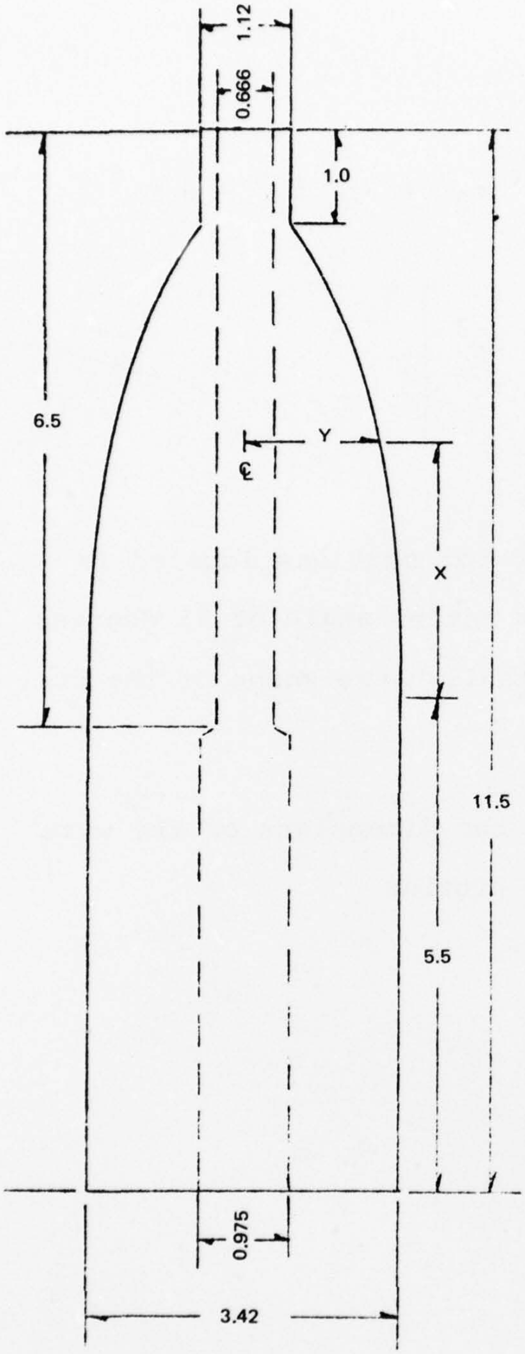

Figure D-4. Boot (Lane Instr. Co.).

X, Y COORDINATES

X	Y(r)
.0	1.71
.5	1.71
1.0	1.71
1.5	1.66
2.0	1.61
2.5	1.54
3.0	1.45
3.5	1.34
4.0	1.20
4.5	1.01
4.75	0.89
5.00	0.73
5.25	0.54

Material
Polyurethane elastomer
Crest #7343/7139*

E = 2810 psi

Note: Polyurethanes should be ether based or amine cured. Do not use ester base for salt water.

Design Parameters

Tether Tension	3600-4400 lbs.
Max. Tether Angle	18°
Rope Diameter	0.677 inches
Min. Bend Radius	12 inches

*Crest Products Company, Santa Ana, Calif.

Part Number: 1057	
Title: Boots for Swaged wire rope fitting.	
Approved: [illegible]	1 of 1

APPENDIX E
COMPARISON STUDY OF OCEAN MODEL BALLAST MATERIALS

The results of the tradeoff study of various test-module ballast materials are presented in Table E-1. This table illustrates the relationship, on a per-float basis, between the dry and flooded weights of the ballast material, the buoyancy attainable, and material cost. The figures in Table 1 were computed using the following criteria:

1. Prices are for steel or concrete only; no fasteners, tether attachments, ballast bases, tethers, floats, and so forth, are included.

2. Reserve buoyancy with ballast blown does not include float buoyancy of 800 pounds.

3. Steel pipe or pilings used in parallel would require brackets to hold pipe bundles. These could also be designed to serve as tether attachments.

4. Dry weight of steel ballast is 1,250 to 1,640 pounds-per-float lighter than concrete pipe or pilings. This could be extremely important from an installation, recovery, handling, and shipping standpoint.

5. Used-rail price is approximately \$85 a ton or \$0.0425 a pound while concrete *pile or pipe is about \$60 a ton or \$0.03 a pound..*

TABLE E-1. COMPARISON OF OCEAN MODEL BALLAST MATERIAL

Five-tire (800 lb.) buoyancy floats

	Dry Weight (per float)	Flooded Weight (per float)	Reserve Buoyancy (per float)	Matl. Cost (per float)
12-inch square concrete pilings (5 in parallel)	3750 pounds	1988 pounds	Need aux Flotation	$126.00
Concrete Pipe				
39-inch diameter, heavy wall Amron	3975 pounds	2107 pounds	556 pounds	$115.00
48-inch diameter, regular wall Amron	3725 pounds	1975 pounds	2059 pounds	$130.00
Steel Pipe				
16-inch, sched 100, heavy wall (3 in parallel)	2475 pounds	2152 pounds	-113.2 pounds	$253.25
18-inch, X Stg, (5 in parallel)	2335 pounds	2033 pounds	497 pounds	$626.75
24-inch, sched 20 (5 in parallel)	2365 pounds	2058 pounds	2674 pounds	$643.25
Chain and Rail	2300 pounds	2000 pounds	Buoyancy not used for recovery	$114.76
Rail Grid	2300 pounds	2000 pounds	Needs Aux Flotation	$ 97.75
58-inch Net Buoys and Rail	2300 pounds	2000 pounds	1092 pounds	$ 68.85
Pipe and Rail				
24-inch, sched 20 (2 in parallel)	2300 pounds	2000 pounds	-106 pounds	$314.84
36-inch, 0.281-inch wall	2300 pounds	2000 pounds	198 pounds (5 ft pipe/float)	$199.02
36-inch, 0.281-inch wall	2300 pounds	2000 pounds	-592 pounds (3.2 ft pipe/float)	$162.65
Corrigated pipe and rail, 36 inch	2300 pounds	2000 pounds	269 pounds	

Five-tire (0.56 density) floats

	Dry Weight (per float)	Flooded Weight (per float)	Reserve Buoyancy (per float)	Matl. Cost (per float)
Pipe and Rail				
36-inch, 0.281 wall*	809 pounds	704 pounds	-150 pounds	$ 58.63
Pontoons and Rail	860 pounds	748 pounds	305 pounds	$ 28.35

55-gallon drum floats

	Dry Weight (per float)	Flooded Weight (per float)	Reserve Buoyancy (per float)	Matl. Cost (per float)
30" (0.281 wall) Pipe and Rails	1222 pounds	1063 pounds	51 pounds	$113.18
32" (0.281 wall) Pipe and Rails	1222 pounds	1063 pounds	207 pounds	$122.89

*Final design

TABLE E-2. ADVANTAGES AND DISADVANTAGES OF THE BALLAST MATERIALS INVESTIGATED

12-inch Square Concrete Pilings (five in parallel)

Advantages	Disadvantages
1. Relatively low cost.	1. 1762 pound/float heavier in air than in H_2O.
2. Shape is inherently stable on bottom.	2. Needs separate flotation.
3. Produced in long lengths.	3. Requires five (each) 12-inch square in parallel (extra handling).
4. Can be installed, retrieved without large craft.	

Concrete Pipe (39-inch Heavy Wall Amron)

Advantages	Disadvantages
1. Good reserve flotation.	1. 1868 pounds per float heavier in air than in H_2O.
2. Relatively inexpensive.	2. Flotation depends upon structural integrity of pipe.
3. Can be installed, retrieved without large craft.	3. Needs base for stability on bottom.
	4. Pipes made only in short sections (8').
	5. Difficult or impractical to form into "barge" configuration.

TABLE E-2. (Cont.)

Concrete Pipe (48-inch Amron)

Advantages	Disadvantages
1. Very high reserve flotation.	1. 1750 pounds per float heavier in air than in H_2O.
2. Relatively inexpensive.	2. Same as 2 for heavy wall.
3. Can be installed without large craft.	3. Same as 3 for heavy wall.
	4. Same as 4 for heavy wall.
	5. Same as 5 for heavy wall.
	6. Difficult or impractical to form into "barge" configuration.
	7. Flotation depends upon air-tight integrity of pipes.
	8. Not made in long sections.

Steep Pipe 16-inch, sched 100 (heavy wall) (three in parallel)

Advantages	Disadvantages
1. Relatively small in-air to in-water weight ratio.	1. Needs separate flotation.
2. Made in long sections.	2. 2 to 1 cost over concrete.
3. Easily made into "barge" configuration.	
4. Can be installed without large craft.	

TABLE E-2. (Cont.)

Steel Pipe (18-inch XStg and 24-inch Sched 20)

Advantages	Disadvantages
1. Relatively small in-air to in-water weight ratio.	1. Requires five parallel pipes for each row of floats.
2. Long sections available.	2. Very expensive (5 to 1 over concrete).
3. Makes into "barge" configuration easily.	
4. Good reserve buoyancy (18").	
5. Very high reserve (24").	
6. Can be installed without large craft.	

Chain and Rail

Advantages	Disadvantages
1. Air/H_2O weight ratio small.	1. Needs heavy duty chain windlass to install, retrieve.
2. Relatively inexpensive.	2. Installation and retrieval depends upon scheduling of proper large craft.

Rail Grid

Advantages	Disadvantages
1. Low air/H_2O weight ratio.	1. Needs separate flotation for installation and retrieval.
2. Relatively inexpensive.	
3. Can be installed without use of large craft.	

TABLE E-2. (Cont.)

58-inch Net Buoys and Rail

Advantages	Disadvantages
1. Very inexpensive (uses "free" net buoys).	1. Not all rail is of same size and weight.
2. Very good reserve buoyancy.	2. Headers or individual water evacuation required for recovery.
3. No large craft needed for installation, recovery.	
4. Nearly inexhaustible supply of scrap rail is continually available.	
5. Easily assembled into "barge" configuration.	
6. Could be designed so only 58" floats were recovered if desired.	

SUMMARY

	ADVANTAGES	DISADVANTAGES
BUOY	1. 1000-pound reserve buoyancy/ float vs 200-pound for pipe	1. Manifold uncertain
	2. Cost less	2. Rail size variations may hinder fabrication
PIPE	1. Neater package	1. Cost more - 50-per cent higher
	2. Simple manifold	
	3. Simple set-up	
PONTOON	1. Neat package	1. Pontoons have to be taken out of water and possibly worked on
	2. Simple manifold	
	3. Simplest set-up	
	4. Least cost	

Tabie E-3 shows the estimated fabrication cost on a per-float basis, the number of floats per ballast assembly, the approximate size of the ballast module, the cost per module, and the cost for a 128-float assembly.

TABLE E-3. SUMMARY OF MATERIAL AND FABRICATION COSTS

	BUOYS AND RAIL ($/buoy)	36-INCH PIPE AND RAIL ($/buoy) (Self Floating)	PONTOON	36-INCH PIPE AND RAIL (no reserve)	PONTOON AND RAIL, 5 TIRE FLOATS (0.56 density)
Materials	$ 69.00	$274.00	$ 80.00	$179.00	$32.35
Weld	41.00	25.00	27.00	27.00	10.50
Set-up	75.00	25.00	25.00	25.00	25.00
Manifold	50.00	9.00	25.00	8.00	11.75
Total	$235.00	$333.00	$157.00	$239.00	$79.60
Floats/module	61	66	60	72	128
Dimension of module	30 ft x 50 ft	30 ft x 55 ft	30 ft x 50 ft	30 ft x 60 ft	28 ft x 60 ft
Cost/module	$14,335	$21,978	$9,420	$17,208	$10,189
Cost/128 Float module	$30,080	$42,624	$20,096	$30,592	$10,189

NOTES:

1. Tether cost – $15/tether (3/8 in. synthetic with boot).
2. 800-pound buoyancy Lane Spherical Float $100–112 (ea) for 100–200 floats.
3. Foaming of 55-gallon drums, $20.80 (ea) for 100 drums, $18.58 (ea) for 200 drums.

APPENDIX F
CALCULATIONS FOR LENGTH OF PIPE & RAIL

For 36″ O.D. pipe (0.281″ wall)
WT = 107.2 lb/ft

Float buoyancy = 828.8 − 464.13 = 364.67 lb
Required ballast wt/float = 2(364.67) ≈ 729.34 lb wet

$$\frac{729.34}{0.87} = 838.32 \text{ lb dry wt}$$

Determine length of pipe required/float: assume tether will have 40 lbs. load with float on surface.

729.34 − 40 = 689.34 lb buoyancy from pipe

Pipe displacement = 6.85 ft^3/ft
= 438.37 lb/ft

$$\text{Pipe length} = \frac{689.34}{438.37} = 1.57 \text{ ft/float}$$

Pipe wt = 1.57 (107.2) = 168.30 lb/float dry
= 146.42 lb/float wet

Rail wt = 729.34 − 146.42 = 582.92 lb/float wet
= 670.02 lb/float dry

Total length of pipe = 1.57 (128) = 200.96 ft ←

Total length of rail = 670.02 (128) $\left(\frac{3}{119}\right)$ = 2162.08 ft ←

APPENDIX G
PRESSURE CALCULATION FOR BALLAST TANK

Use 36 inch O.D. steel pipe with 0.281 inch wall.

1. $$S = \frac{\rho R}{t}$$ Internal pressure (yield)

$$36000 = \frac{\rho(18)}{.281}$$

$$\rho = 562 \text{ psi}$$

2. $$\rho_u = 2\, S_u \frac{b-a}{b+a}$$ Internal burst

$$\rho_u = 2(55000)\, \frac{18-17.719}{18+17.719}$$

$$\rho_u = 865 \text{ psi}$$

3. $$\rho' = \frac{t}{R}\, \frac{Sy}{1 + 4\frac{Sy}{E}\left(\frac{R}{t}\right)^2}$$ External collapse

$$\rho' = \frac{.281}{18}\, \frac{36000}{1 + 4\, \frac{36000}{29(10)^6}\left(\frac{18}{.281}\right)^2}$$

$$\rho' = 26.3 \text{ psi}$$

4. $$\rho' = \frac{1}{4}\, \frac{E}{1-\nu^2}\, \frac{t^3}{R^3}$$ External collapse for long tube

$$\rho' = \frac{1}{4}\, \frac{29(10)^6}{1-.27^2}\left(\frac{.281^3}{18^3}\right)$$

$$\rho' = 29.7 \text{ psi}$$

5. $$\rho' = .807\, \frac{Et^2}{\ell R}\, \sqrt[4]{\left(\frac{1}{1-\nu^2}\right)^3 \frac{t^2}{R^2}}$$ External collapse for tube head circular at 8 ft. intervals

$$\rho' = .807\, \frac{29(10)^6\,(.281)^2}{96(18)}\, \sqrt[4]{\left(\frac{1}{1-.27^2}\right)^3 \frac{.281^2}{18^2}}$$

$$\rho' = 141.4 \text{ psi}$$

APPENDIX H

TABLE H-1. DIMENSIONS OF STANDARD RAILS (LETTERS REFER TO FIG.)

Standard and nominal weight		Weight per yd, lb	Dimensions, in.				Distribution of metal			Axis l-l	
			a	b	c	d	Percent head	Percent web	Percent base	I, in.^{4}	S, in.^{3}
P.S.	155	155.5	8	6-3/4	3	3/4	33.1	27.9	39.0	130.9	37.4
AREA	140	140.6	7-5/16	6	3	3/4	37.0	25.0	38.0	95.6	28.2
C.F. & I.	136	136.2	7-5/16	6	2-15/16	11/16	36.4	27.1	36.5	94.9	28.3
L.V.	136	137.363	7	6-1/2	2-15/16	11/16	34.8	24.5	40.7	86.7	28.3
AREA	133	133.4	7-1/16	6	3	11/16	36.3	26.5	37.2	86.0	27.0
AREA	132	132.1	7-1/8	6	3	21/32	34.1	28.3	37.6	88.2	27.6
H.F.	132	132.4	7-5/16	6	2-31/32	21/32	35.8	26.7	37.5	93.8	28.4
AREA	131	130.8	7-1/8	6	3	21/32	35.0	27.0	38.0	88.5	27.6
C.B. & Q.-T.R.	129	129.4	7-5/16	6	2-5/8	21/32	32.9	28.7	38.4	90.4	28.1
N.Y.C.	127	127.5	7	6-1/4	3	21/32	34.2	26.4	39.4	81.57	26.4
C.F. & I.	119	118.8	6-13/16	5-1/2	2-21/32	5/8	37.1	26.1	36.8	71.4	22.9
AREA	115	114.7	6-5/8	5-1/2	2-23/32	5/8	34.8	27.1	38.1	65.6	22.0
H.F.	113	113.2	6-13/16	5-1/2	2-11/16	19/32	36.4	25.0	38.6	69.8	22.8
C.B. & Q.-T.R.	112	112.3	6-3/4	5-1/2	2-1/2	5/8	34.3	26.7	39.0	67.0	22.3
AREA	112	112.3	6-5/8	5-1/2	2-25/32	19/32	35.9	25.1	39.0	65.5	21.8
N.Y.C.	105	104.7	6	5-1/2	3	5/8	40.9	24.0	35.1	49.9	17.3
AREA	100	101.5	6	5-3/8	2-11/16	9/16	38.2	22.6	39.2	49.0	17.8
A.R.A.-A.	100	100.4	6	5-1/2	2-3/4	9/16	36.9	23.4	39.7	48.9	17.8
A.R.A.-B.	100	100.5	5-41/64	5-9/64	2-21/32	9/16	40.2	19.2	40.6	41.3	15.7
ASCE	100	100.4	5-3/4	5-3/4	2-3/4	9/16	42.0	21.0	37.0	44.0	16.1
A.R.A.-A.	90	90.0	5-5/8	5-1/8	2-9/16	9/16	36.2	24.0	39.8	38.7	15.2
A.R.A.-B.	90	90.5	5-17/64	4-49/64	2-9/16	9/16	40.1	19.2	40.7	32.3	13.2
ASCE	90	90.1	5-3/8	5-3/8	2-5/8	9/16	42.0	21.0	37.0	34.4	13.5
ASCE	85	85.0	5-3/16	5-3/16	2-9/16	9/16	42.0	21.0	37.0	30.1	12.2
ASCE	80	80.2	5	5	2-1/2	35/64	42.0	21.0	37.0	26.38	11.08
ASCE	75	74.8	4-13/16	4-13/16	2-15/32	17/32	42.0	21.0	37.0	22.86	9.94

I = moment of inertia of section; S = section modulus; l-l = neutral axis.

P.S. = Pennsylvania Section (P.R.R.); C.F. & I. = Colorado Fuel & Iron; H.F. = Head Free; L.V. = Length Valley; C.B. & Q.-T.R. = Chicago, Burlington & Quincy – Torsion-resisting; N.Y.C. = New York Central.

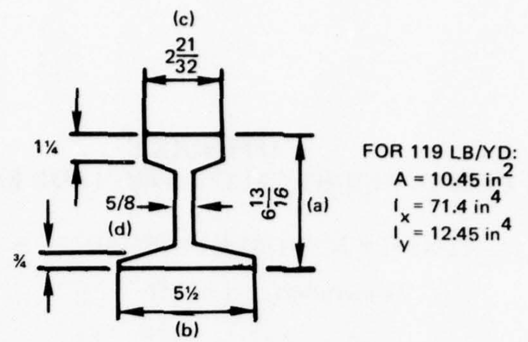

Figure H-1. Standard rail section.

APPENDIX I
INITIAL WEIGHT CALCULATION FOR BALLAST

Top grid	[14(28) + 2(29-1/3) + 11(59)] 40	=	43,987
	27 members 1100 ft		
Bottom	[2(29-1/3) + 9(59) + 14(28)] 40	=	39,267
	25 members 982 ft		
Vertical	[6(3-1/2)] 40	=	840
	6 members 21 ft		
Straps	$\left[\left(\frac{36\pi}{2} + 36\right)(10)(.375)\frac{485}{1728}\right] 28$	=	2,727
	28 members 97.4# ea		
Pipe	55(4)(107.2)	=	23,584
Tether pipe	$128\left(\frac{10}{12}\right)(8.15)$	=	870
Gussets		=	560
Zincs	28(24)	=	672
4″ pipe	∿40 ft	=	400
			112,907
Welds	2%		2,258
	→ Weight dry		115,165
	→ Weight wet (87%)		100,194
Wet wt required	375 (128) (2)	=	96,000
Buoyancy	55 (4) (438.4#/ft)	=	96,448
Tether tension	100,194 −96,448		
	3,746 ÷ 128	=	29.3#/float

APPENDIX J
STRESS CALCULATIONS FOR LIFT

TOTAL WEIGHT OF ASSEMBLY (BALLAST PLUS FLOATS) IS 175,800 LB.

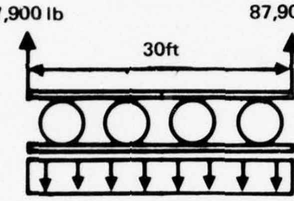

Figure J-1.

$m = 5860\,(15)\,(7.5)\,(12) - 87900\,(15)(12)$ $\qquad s = \dfrac{mc}{I}$

$m = 7{,}911{,}000$ in-lb

$$s = \frac{7{,}911{,}000\,(24.81)}{155{,}333.98}$$

$s = \underline{1{,}263.55 \text{ psi}}$ Bending stress (lateral)

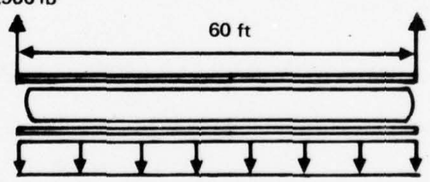

Figure J-2.

$m = 2930\,(30)\,(15)\,(12) - 87900\,(30)(12)$

$m = 15{,}822{,}000$ in-lb

$$s = \frac{15{,}822{,}000\,(24.81)}{88{,}535.53}$$

$s = \underline{4{,}433.74 \text{ psi}}$ Bending stress (longitudinal)

MOMENT OF INERTIA (LATERAL PLANE):

$$I_{total} = 4\,I_{tank} + [I_{top} + Ad^2] + [I_{bottom} + Ad^2]$$

$$I_{tank} = \frac{\pi}{4}(R^4 - r^4)$$

$$I_{tank} = \frac{\pi}{4}(18^4 - 17.719^4)$$

$$I_{tank} = 5029.11\ in^4$$

$$I_{top} = 3(71.4) + 8(12.45) = 313.8\ in^4$$

$$I_{bottom} = 7(71.4) + 2(12.45) = 524.7\ in^4$$

$$I_{total} = 4(5029.11) + [313.8 + 11(10.45)(14.59)^2] + [524.7 + 9(10.45)(21.41)^2]$$

$$\underline{I_{total} = 88{,}535.53\ in^4}$$

MOMENT OF INERTIA (LONGITUDINAL PLANE):

$$I_{total} = [I_{top} + Ad^2] + [I_{bottom} + Ad^2]$$

$$I_{top} = 14(71.4) + 2(12.45) = 1024.5\ in^4$$

$$I_{bottom} = 14(71.4) + 2(12.45) = 1024.5\ in^4$$

$$I_{total} = [1024.5 + 16(10.45)(21.41)^2] + [1024.5 + 16(10.45)(21.41)^2]$$

$$\underline{I_{total} = 155{,}333.98\ in^4}$$

BEAM STRESSES RESULTING FROM DEBALLASTING TANKS

Assume one outboard tank deballasted and other fixed:

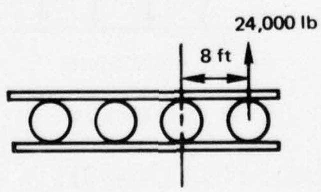

Figure J-3.

$$m = 24000\ (8)(12)$$
$$m = 2{,}304{,}000\ \text{in-lb}$$

$$s = \frac{2304000\ (24.81)}{155333.98}$$

$s = \underline{368.00 \text{ psi}}$

Assume two tanks deballasted:

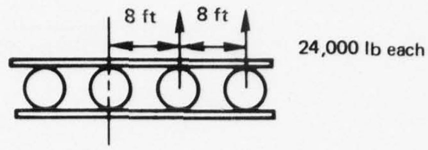

Figure J-4.

$m = 24{,}000\,(16)\,(12) + 24000\,(8)\,(12)$
$m = 6{,}912{,}000$ in-lb

$$s = \frac{6912000\,(24.81)}{155333.98}$$

$s = \underline{1{,}103.99 \text{ psi}}$

Assume three tanks deballasted:

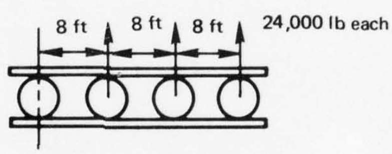

Figure J-5.

$m = 24000\,(24)\,(12) + 24000\,(16)\,(12) + 24000\,(8)\,(12)$
$m = 13{,}824{,}000$ in-lb

$$s = \frac{13824000\,(24.81)}{155333.98}$$

$s = \underline{2{,}207.97 \text{ psi}}$

WELD CALCULATIONS

Tether Sockets

For 1/8 inch fillet welds, 1 inch long at top and bottom on each side of socket.

$$s = \frac{375 \text{ lb/float}}{.125(.707)(4)}$$

$s = \underline{1060.82 \text{ psi}}$

Tank Strap Gussets (¼ inch weld)

Total load = 375 lb/float (128) = 48,000 lb

$$s = \frac{48000}{.25(.707)(6)(4)(28)}$$

$$s = \underline{404.12 \text{ psi}}$$

Tank Straps (¼ inch weld)

Total load = 48,000 lb

$$s = \frac{48000}{.25(.707)(10)(4)(28)}$$

$$s = \underline{242.47 \text{ psi}}$$

APPENDIX K
SPLICE PLATE CALCULATIONS

½″ X 3″ splice plates were used in joining both halves of the ballast. Assume moment of inertia is based only on these plates. (16 pieces on top and bottom)

$$I' = I + Ad^2$$

$$I' = 32\left[\frac{.5(3)^3}{12}\right] + 32(.5)(3)(21.41)^2$$

$$I' = 22{,}038.63 \text{ in}^4$$

For lifting ballast plus floats, bending stress is:

$$m = 7{,}911{,}000 \text{ in-lb} \qquad s = \frac{mc}{I'}$$

$$s = \frac{7911000\ (22.91)}{22038.63}$$

$$s = \underline{8{,}223.79 \text{ psi}}$$

APPENDIX L
FINAL WEIGHT CALCULATION FOR BALLAST

Rail	2081.5 ft @ 119 lb/yd		82,566 lb
Tank	54(118.92)(4) + 98(8)		26,471 lb
Strap	$92.54(10)(.375)(28)\frac{485}{1728}$		2,727 lb
Pipe and Fittings	$\sim 40(10) + 100$		500 lb
Zinc	24(28)		672 lb
Gusset	Tank	$\frac{1}{2}(6)(12)(56)\frac{485}{1728}$	566 lb
	Bottom	$\frac{1}{2}(5\frac{1}{2})(5\frac{1}{2})(6)\frac{485}{1728}(\frac{1}{2})$	13 lb
	Top	$\frac{1}{2}(7\frac{13}{16})(7\frac{13}{16})(4)\frac{485}{1728}(\frac{1}{2})$	17 lb
Standoff	$\frac{3}{4}(2\frac{7}{16})(11)(42)\frac{485}{1728}$		237 lb
Socket	$\frac{5}{12}(4.64)(128)$		247 lb
Weld			600 lb
Splice Plate	$\frac{1}{2}(3)(20)(32)\frac{485}{1728}$		269 lb
		Total	114,885 lb

Rail	Bottom	14.125 (14) = 197.75
	½	14.667 (2) = 29.33
		58.917 (2) = 117.83
		7.083 (12) = 84.99
		5.0 (4) = 20.00
		449.91 × 2 = 899.83 ft
	Top	58.917 (5) = 294.59
	½	14.667 (2) = 29.33
		14.125 (14) = 197.75
		521.67 × 2 = 1043.34 ft

Vert	3.417 (6)	= 20.50		
CL	58.917 (2)	= 117.83		
		138.33 ft		2081.50 ft Total (693.83 yd)

for 119 lb/yd rail $\boxed{82{,}565.77 \text{ lb}}$

for 112 lb/yd rail 77,708.96 lb

Weight Correction (based on 112 lb/yd rail)

½ bottom (32nd St)
14.125 (8) = 113.00
19.875 = 19.875
132.875 ft = 44.292 yd = 310.04 lb DIFF @ 119 lb/yd

½ top (32nd St)
58.917 ft = 19.639 yd = 58.92 lb DIFF @ 115 lb/yd

19.875 (2) = 39.75 ft = 13.25 yd = 92.75 lb DIFF @ 119 lb/yd

½ bottom (Shop)
14.125 (4) = 56.5
19.833 = 19.833
76.333 ft = 25.444 yd = 178.11 lb DIFF @ 119 lb/yd

½ top (Shop)
14.125 (2) = 28.250
14.667 = 14.667
58.917 (3) = 176.751
20 = 20
239.668 ft = 79.889 yd = 559.23 lb DIFF @ 119 lb/yd

Total DIFF 1,199.05 lb

for 112 lb/yd rail	wt = 77,708.96	82,565.70 design wt. for 119 lb/yd rail
	= +1,199.05	−78,908.01
	78,908.01 lb	3,657.76 lb

→ Add 3,658 lb = 32.66 yd = 97.98 ft of 112 lb/yd RAIL

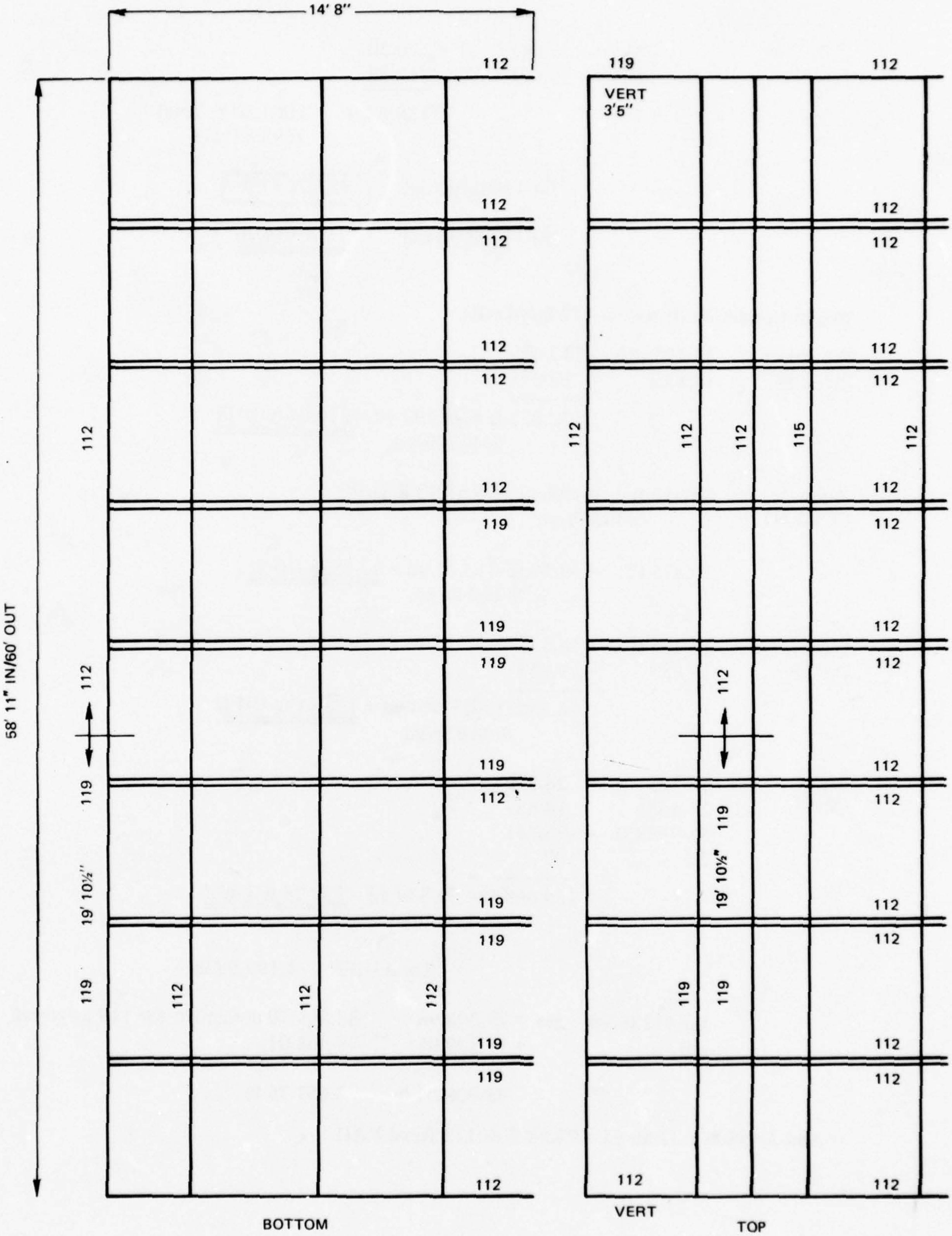

Figure L-1. Rail grid layout (first half of Module No. 1).

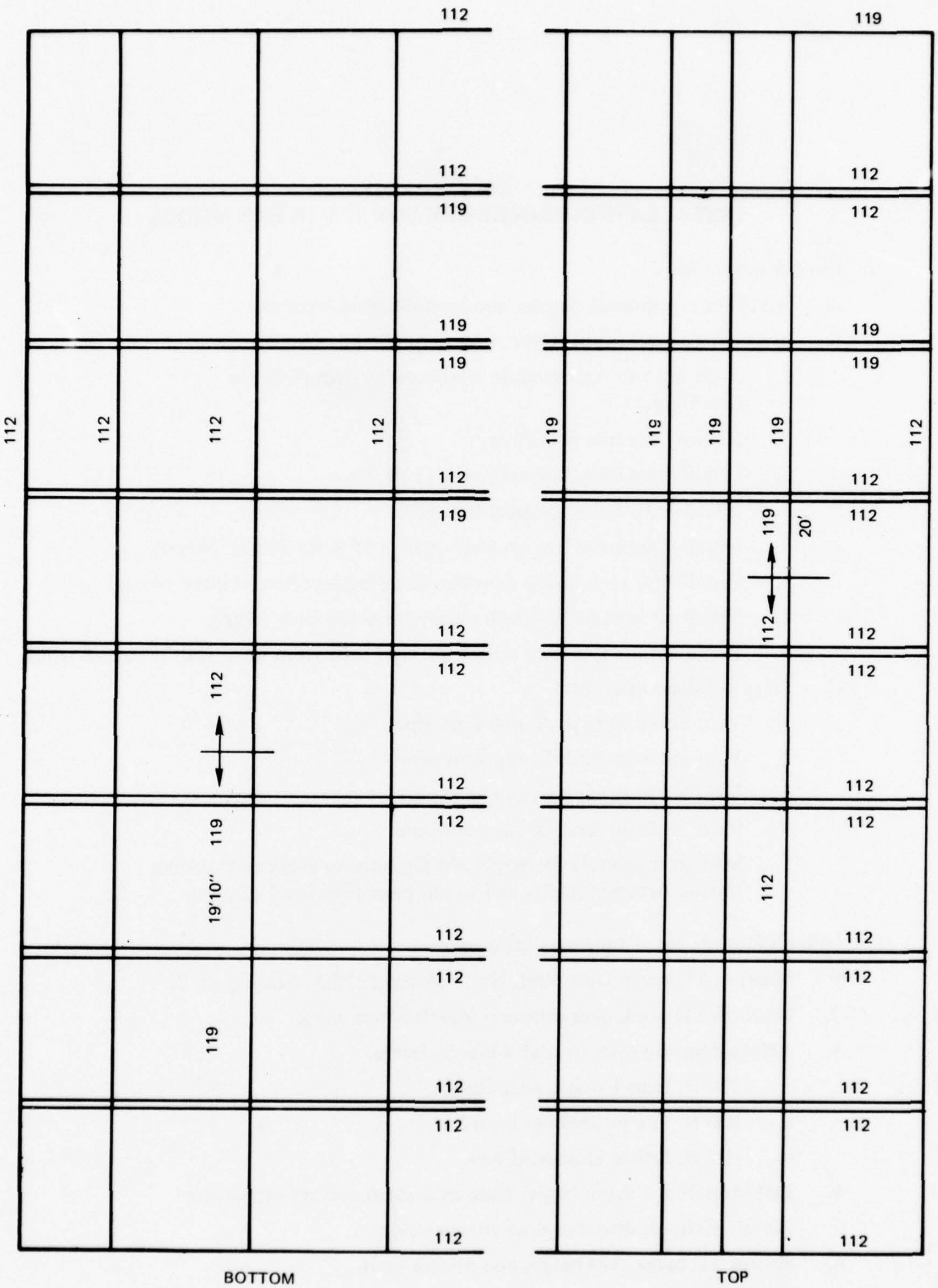

Figure L-2. Rail grid layout (second half of Module No. 1).

APPENDIX M
INSTALLATION PROCEDURE FOR TFB OCEAN MODEL

I. Float Module No. 2

A. Assemble equipment on pier and layout for operations.

B. Start diving operations, prepare to float Module No. 2

1. Shift tag line A to module starboard quarter (100 ft). See Figure 1.
2. Remove tag line B (100 ft.).
3. Install line G on starboard bow (120 ft.).
4. Install 300 ft. line on port bow (C).
5. Install composite line on port quarter (J & K) 310 ft. overall.
6. Install four inch inside diameter interconnect hoses (three pieces)
7. Install air hose at two-inch inside-diameter blow fitting.
8. Remove four two-inch standpipe vent caps from deep end of ballast tanks.

C. Start deballast operation.

1. Vent air from tank A; cap vent pipe.
2. Vent air from tank B; cap vent pipe.
3. Vent air from tank C; cap vent pipe.
4. Vent air from tank D; cap vent pipe.
5. Maneuver module by hand-held tag lines to assigned mooring station between Alpha and Bravo piers near head of pier.

II. Launch Module No. 1 by crane from barge.

1. Position YC barge with Mod. No. 1 alongside YD. See Figure 2.
2. Position YD hook over unit and attach lifting sling.
3. Attach four tag lines to unit while on barge.
   a. 200 ft. lines to each port corner.
   b. 100 ft. line to starboard quarter.
   c. 102 ft. line to starboard bow.
4. Lift Mod. No. 1 from barge, train over stern and set into water.
5. Tie off all lines; divers remove lifting straps.
6. Secure YC barge, YD barge, and pusher boat.
7. Shift Mod. No. 1 to pre-towing position and secure for overnight berthing. See Figure M-3.

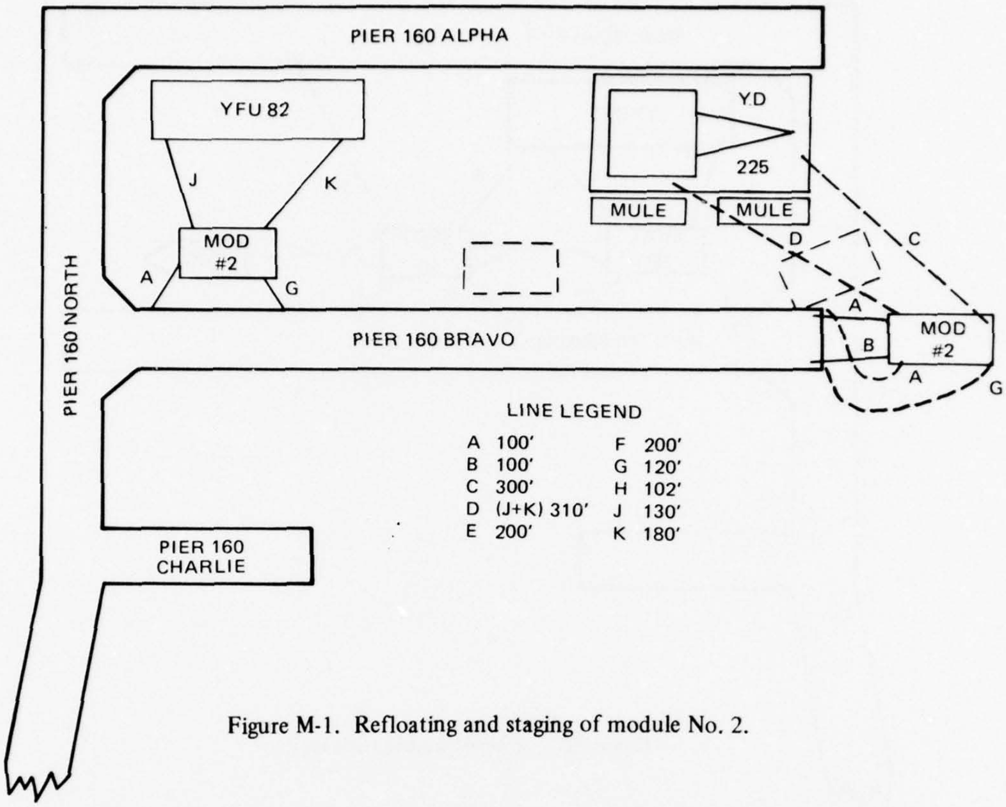

Figure M-1. Refloating and staging of module No. 2.

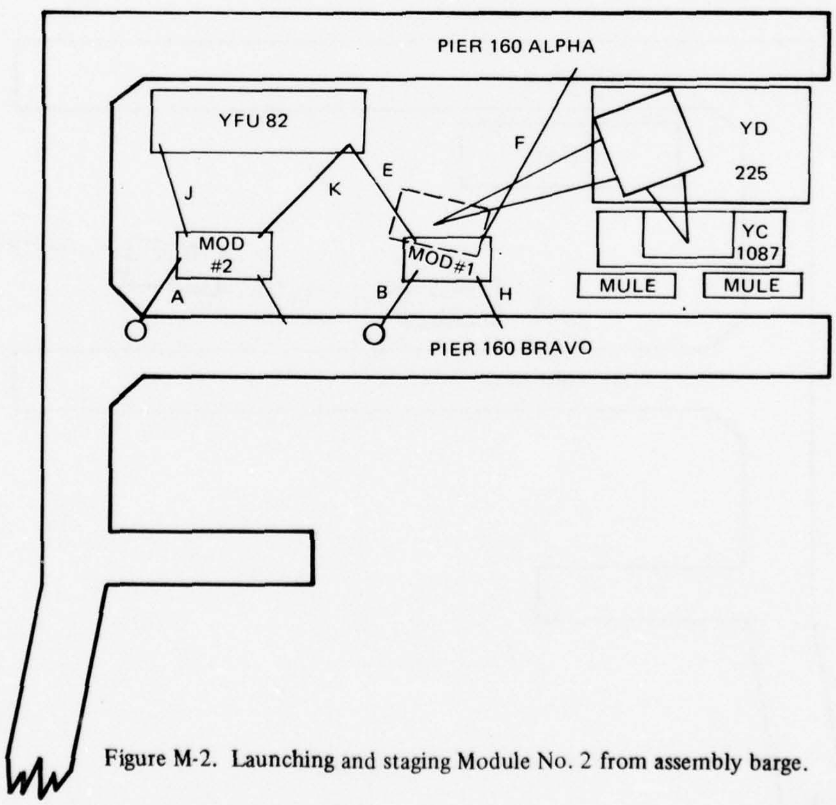

Figure M-2. Launching and staging Module No. 2 from assembly barge.

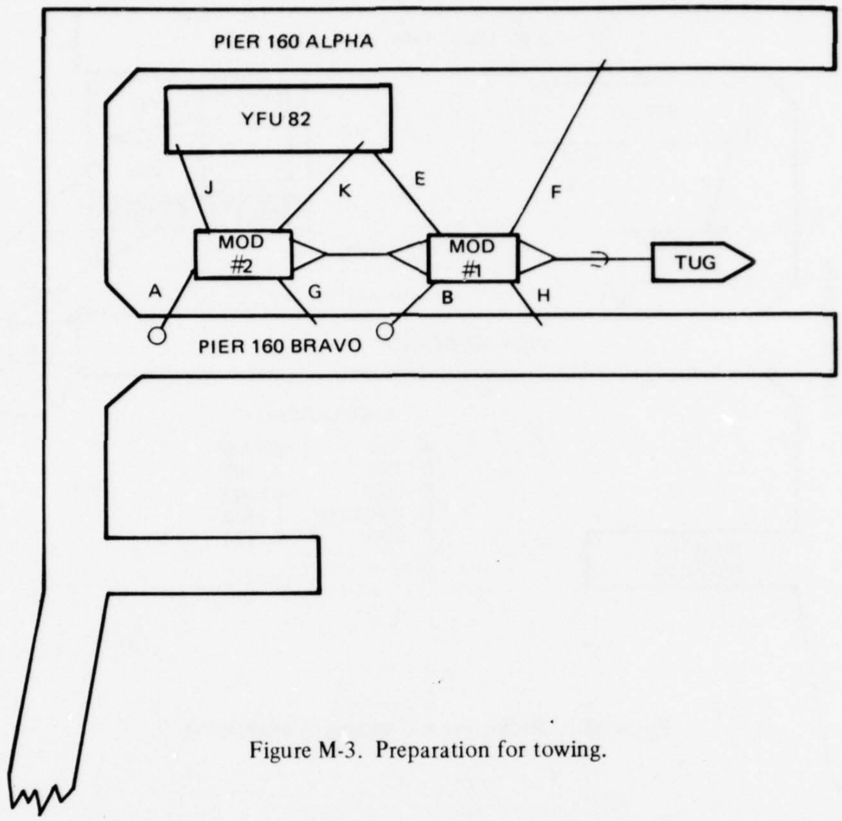

Figure M-3. Preparation for towing.

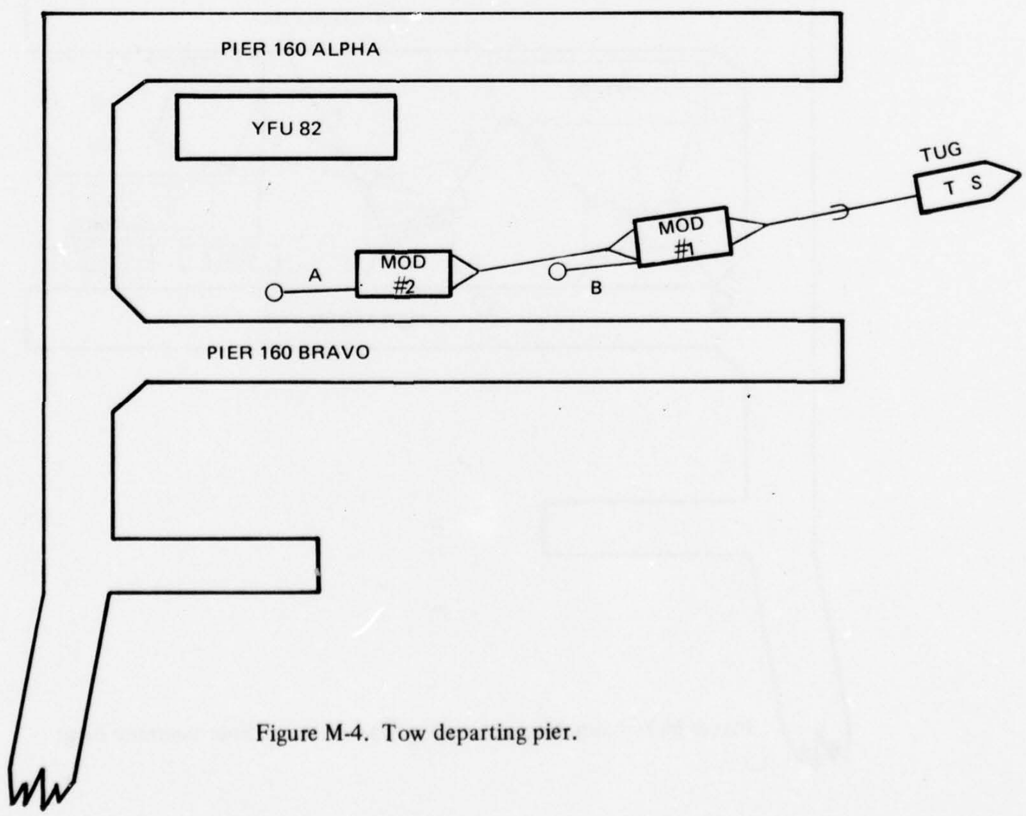

Figure M-4. Tow departing pier.

8. Install inter-mod. towing bridle.
9. Install forward towing bridle.
10. Attach buoys to starboard quarter lines of both units.
11. Secure from launching and handling operations.
12. Prepare auxiliary equipment for transfer to diving boat including:
    a. Eight 4-inch by 15-ft flooding hoses.
    b. Two 2-inch by 60-ft vent hoses.
    c. Two 1-inch by 100-ft dewatering hoses.
    d. Assorted lines, tools and consumable supplies plus ten divers bottles per equipment list.
13. Load boat and secure for early start.

III. Tandem tow of breakwater modules to installation site.

1. After tow craft PTS CORONADO arrives at NOSC, conduct on-site briefing with divers, dive boatmaster, tug captain and personnel; distribute radios.
2. Make up forward tow bridle to tug; begin to stand out from pier.
3. Mooring lines securing TFB modules to pier are thrown off by divers, in pairs, starting with forward set. Tug takes up slack as modules are freed.
4. Tug has custody of TFB tow. See Figure M-4.
5. Personnel on pier recover mooring lines and shackles.
6. Diving boat go alongside pier and pickup each mooring line from place it was recovered from water. Finally, take aboard line handlers and proceed after TFB under tow.
7. Dive boat pick up divers from small boat; take workboat in tow.
8. PTS CORONADO proceed out channel at slow speed with short tow line.
9. From buoy #6 tug takes new course at 135° T and stream out towline to 350 ft. Install dynomometer to monitor towing forces.
10. Arrive at the operation area staging buoy. Divers embarked in workboat to pick up buoyed trailing line.
11. Trailing line is secured to staging moor; transit to installation site is complete. See Figure M-5.
12. Start procedure to rig breakwater modules for mooring and flooding.
    a. Transfer trailing line B and shackle to starboard forward corner of Module No. 1.
    b. Install additional shackle to starboard aft corner of Mod. No. 2
    c. Pass free end of line B through the shackle just installed and secure to surface buoy (12 in. dia).
    d. Install six pieces of 4-inch-diameter by 15-feet buoyancy tank interconnect hoses on both mods.

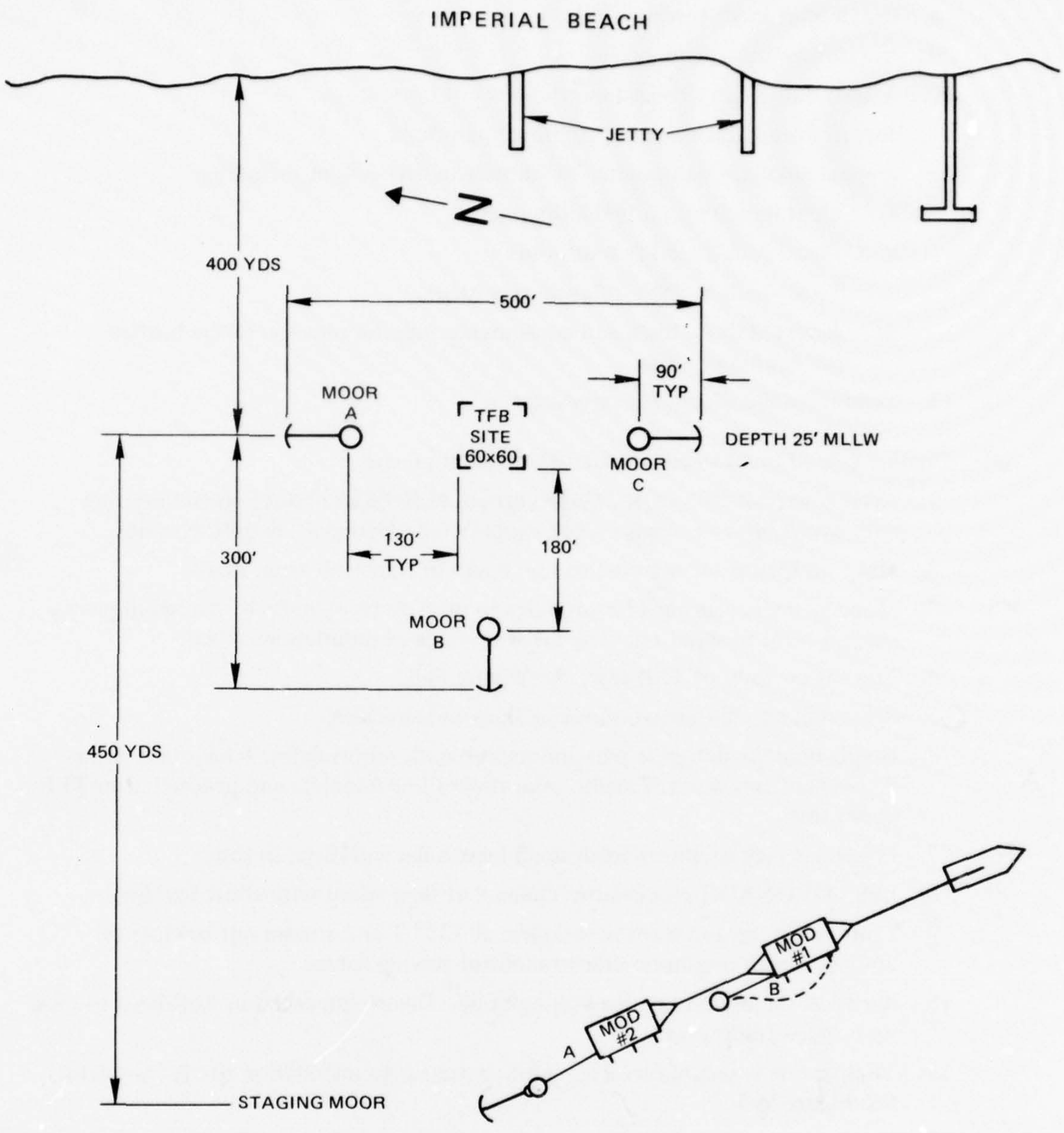

Figure M-5. Arrival at mooring site.

e. Tugboat maneuver the No. 1 mod clockwise to bring units side by side. Workboat maintains tension on line B throughout maneuvering to draw mods into alignment side by side. See Figure M-6.

f. Install 12-inch diameter yellow marker floats on the two-inch main vent valve of each raft assembly.

g. Divers shackle dangling interconnect chains (three places) together as soon as modules are close enough. DANGER – swimmers were required to exercise caution when working below the modules, being careful not to blunder between the structures – the possibility for severe injury existed.

h. Disconnect both ends of the inter-module tow bridle and pass to workboat. Retrieve bridle from water and stow aboard diving boat. Leave shackle on starboard quarter of Mod. No. 1.

i. Disconnect tow bridle from leading end of Mod. No. 1 and pass entire bridle to workboat. Reposition tugboat off port side of Mod. No. 2, stern-to. Assemble tow bridle with port side of Mod. No. 2 and return free end to tugboat. See Figure M-7.

j. Transfer mooring lines J, K and G, to workboat. Install line J on port side of Mod. No. 1, assembling with wire strap and shackle provided on ballast assembly. Attach a 12-inch diameter yellow float to end of line and cast off. Install line K to starboard aft corner of Mod No. 1 using shackle left in place in h. above. Install 12 inch yellow float and cast off. Install line G to ring in tow bridle. Pass free end to deck of tow craft.

k. Tugboat maneuver to remove slack from towing bridle and relieve tension on the mooring line to the staging buoy.

l. Divers cast off mooring line from the raft. Disconnect line from mooring buoy and pass to workboat for recovery.

m. Tugboat maneuver with breakwater in tow, to pass through center of mooring buoy triangle such that the trailing lines can be shackled to mooring buoy by workboat personnel. Connect line J to the north shoreward buoy, then connect line K as the module comes abreast. Finally, line G is passed to south mooring buoy holding the breakwater assembly in the proper location and attitude for bottom emplacement. See Figure M-8.

n. Flood four ballast tanks joined in series with the four inch flood port on tank A, and a vent hose to the surface on tank D.

o. Flood the second module in same manner.

p. Clean up of underwater equipment after the flooding is complete which involved the following:

   1. Remove towing bridle and release tugboat from the project. Return the tow bridle to the diving boat.

   2. Remove mooring lines J, K, and G, and return to diving boat.

   3. Remove 4-inch interconnect hoses and the two 2-inch vent hoses and return these to the diving boat.

   4. Install a length of one-inch diameter polypropylene buoyant line between the breakwater assembly and the seaward mooring Buoy B.

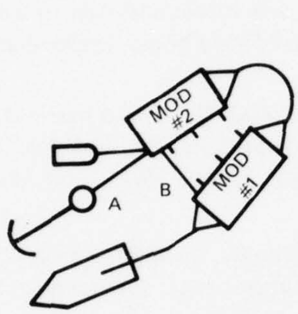

Figure M-6. Linkage of modules
(staging moor)

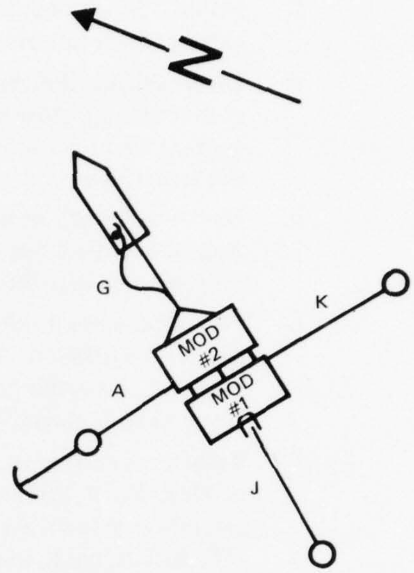

Figure M-7. Preparation for mooring
(staging moor).

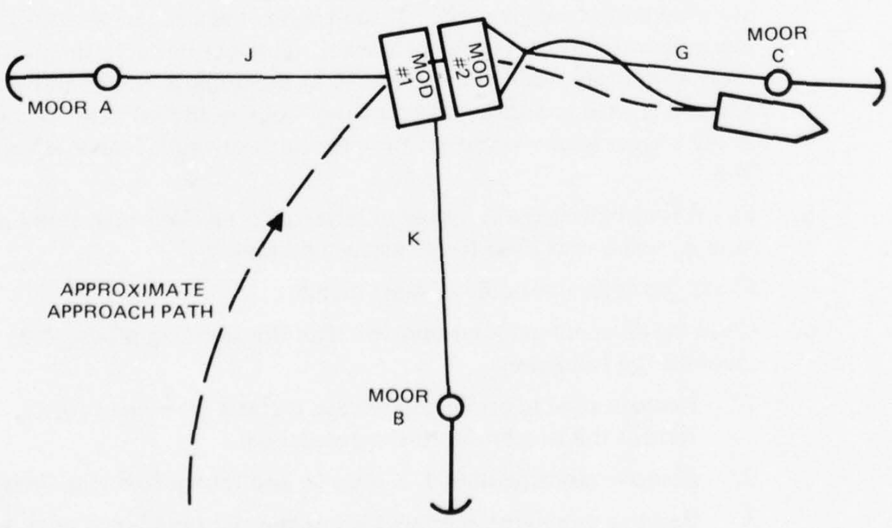

Figure M-8. Maneuvering into mooring position
(TFB Site).

Haul the line down as tightly as possible and secure to the bottom-resting chain of the moor. This line is to serve as a "tattletale" between the breakwater assembly, and a fixed reference point on the ocean floor. If tide and storm influences prompt the breakwater to shift position, then tension change of this buoyant line will serve as a measurable indicator.

q. This installation completes the task of locating the breakwater.

APPENDIX N
DRAG CALCULATION FOR TFB UNDER TOW

Assume total drag is based on effective frontal area of the ballast and the lead row of flats.

Frontal area of ballast:

$$A_B = 4\pi R^2 + 2bh + 3bh \qquad \text{(4 tanks + rail)}$$
$$A_B = 4\pi(1.5)^2 + 2(30)(.5) + 3(.5)(3)$$
$$A_B = 62.77\ ft^2$$

Frontal area of floats:

$$A_F = 8\pi R^2 \qquad \text{(8 floats in lead row)}$$
$$A_F = 8\pi(\frac{13.25}{12})^2$$
$$A_F = 30.64\ ft^2$$

Total frontal area = 62.77 + 30.64 = 93.41ft^2

$$\text{Drag} = \frac{1}{2}\rho V^2 A\ C_D$$
$$D \approx V^2\,(93.41)(1.2)$$
$$D \approx 112.09V^2$$

1 knot = 1.667 ft/sec

TABLE N-1.

Speed (kt)	One Module Drag (lbs)	Two Modules Drag (lbs)
1	311.49	622.98
2	1245.94	2491.88
3	2803.37	5606.74
4	4983.77	9967.54

TABLE N-2.

For speeds recorded during tow:

Speed (kt)	Drag (lb) Calc	Drag (lb) Dynomometer
1.89	2225.32	4500
2.53	3987.58	5500
3.16	6220.74	7000

The calculated values for drag approximate those recorded during the tow to Imperial Beach. Several factors, however, remain unknown: (1) flow pattern between adjacent ballast tanks and floats, (2) actual orientation and real frontal area of all floats, and (3) effect of prop wash from tug on recorded drag.

APPENDIX O
ACTUAL SEQUENCE OF OPERATIONS – TFB OCEAN MCDEL INSTALLATION

I. Floating of Module No. 2 on 11 April 1978.

A. Assemble equipment on pier and layout for operations started at 0800 hours.

B. 0830 hours. Started diving operations, prepared to float Mod. No. 2.

1. Shifted tag line A to raft starboard quarter (100 ft.) See Figure O-1.
2. Removed tag line B (100 ft.)
3. Installed line G on starboard bow (120 ft.)
4. Installed 300-ft line on port bow (C)
5. Installed composite line on port quarter (J & K) 310 ft overall.
6. Installed 4-in ID interconnect hoses (3 pieces)
7. Installed air hose at 2-in ID blow fitting.
8. Removed four 2-inch standpipe vent caps from deep end of ballast tanks.
9. Submerged raft is ready to deballast.

C. Start deballast operation at 0943 hours

1. Vent air from tank A at 0957 hours (14 min. elapsed time) cap vent pipe.
2. Vent air from tank B at 1006 hours (9 min. elapsed time) cap vent pipe.
3. Vent air from tank C at 1016 hours (10 min. elapsed time) cap vent pipe.
4. Vent air from tank D at 1022 hours (6 min. elapsed time) cap vent pipe.
5. Unit was freed from bottom but not completely deballasted
6. Maneuvered mod. by hand-held tag lines to assigned mooring station between Alpha and Bravo piers near head of pier.
7. Module passed end of pier, but starboard quarter line fouled submerged object on pier and stopped progress on that corner. Module rotated counter-clockwise.
8. Port bow line from mod. passed under propeller stem of pusher boat moored to YD barge, on opposite side of Alpha pier and became fouled.
9. Starboard bow of module was hauled by hand back toward Bravo pier, and divers cleared fouled tag lines.
10. Module was then walked easily along the length of Bravo pier 420 feet and moored at the base of pier. Completed at 1110 hours.

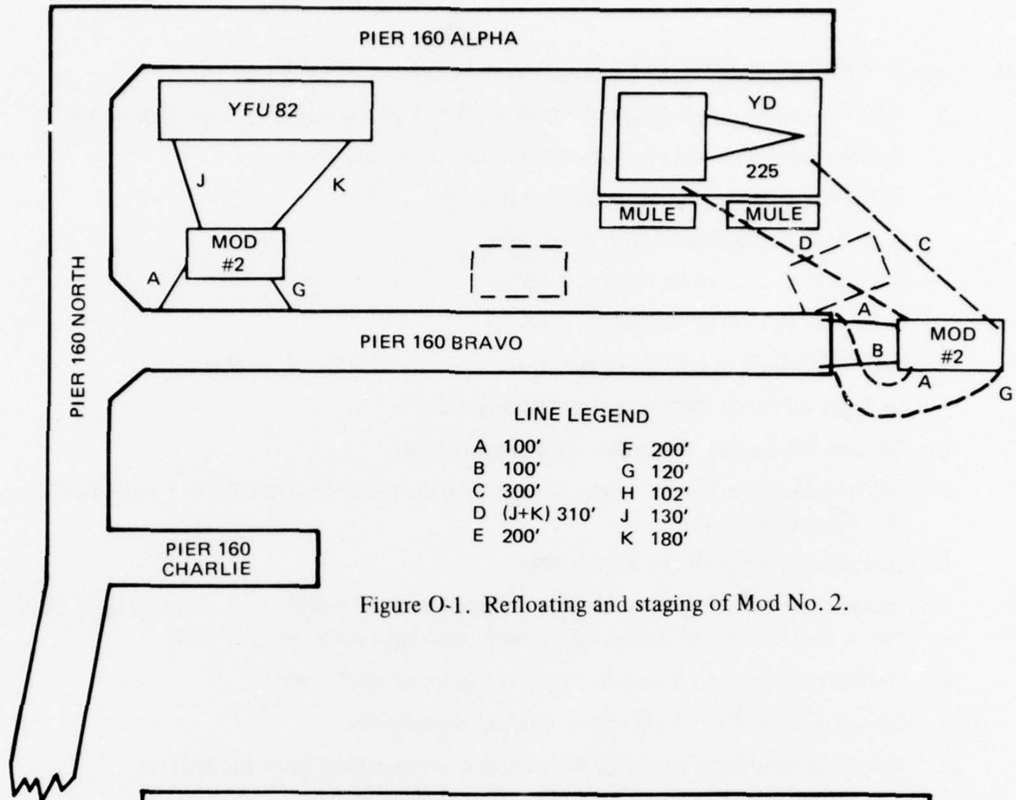

Figure O-1. Refloating and staging of Mod No. 2.

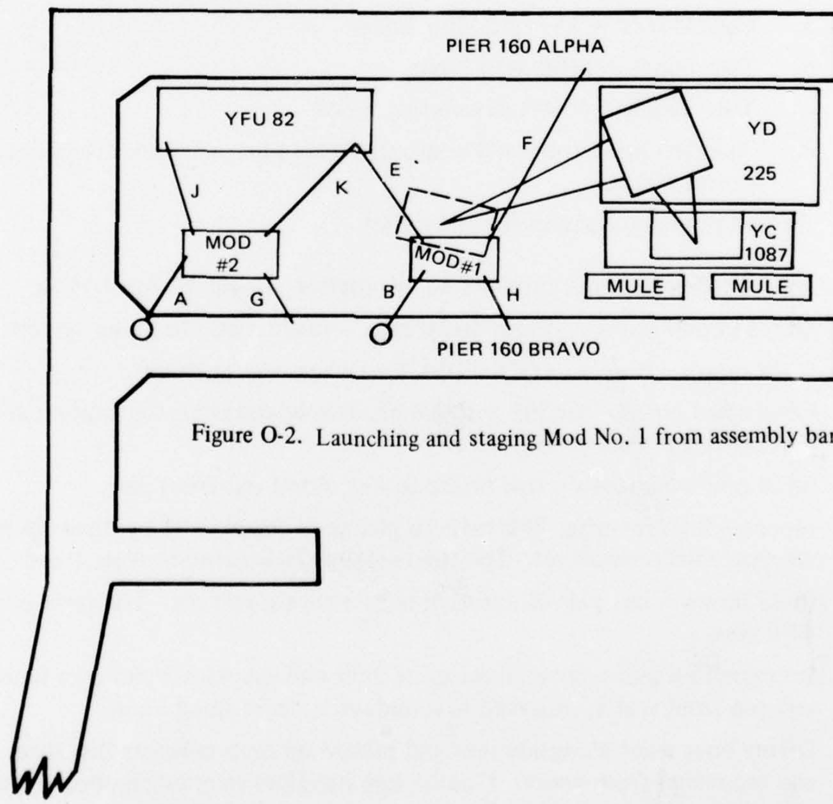

Figure O-2. Launching and staging Mod No. 1 from assembly barge.

II. Launching of Module No. 1 by crane from barge on 11 April 1978.

1. 1200 – position YC barge with Mod. No. 1 alongside YD. See Figure O-2.
2. Positioned YD hook over mod. and attach lifting sling.
3. Attached four tag lines to mod. while on barge.
   a. 200-ft lines to each port corner.
   b. 100-ft line to starboard quarter.
   c. 102-ft line to starboard bow.
4. Lifted Mod. No. 1 from barge, train over stern and set into water.
5. Tied off all lines; divers remove lifting straps.
6. Secure YC barge, YD barge, and pusher boat.
7. Shifted Module No. 1 to pre-towing position and secure for overnight berthing. See Figure O-3.
8. Installed inter-mod. towing bridle.
9. Installed forward towing bridle; reconnected air line to ballast tank D of Mod. No. 1 and complete deballasting (ref: this appendix, para I. C-5).
10. Attached buoys to starboard quarter lines of both mods.
11. Secured from launching and handling operations.
12. Prepared auxiliary equipment for transfer to diving boat including:
    a. Eight 4-inch × 15-ft flooding hoses
    b. Two 2-inch × 60-ft vent hoses
    c. Two 1-inch × 100-ft dewatering hoses.
    d. Assorted lines, tools and consumable supplies, plus ten divers bottles per equipment list.
13. Loaded boat and secured for early start.

III. Tandem tow of breakwater modules to installation site on 12 April 1978.

1. Started 0500 hours – divers dress, etc., – made ready to make up tow.
2. 0545 hours – tow craft PTS CORONADO arrived at NOSC.
3. Conducted on-site briefing with divers, dive boatmaster, tug captain and personnel; distributed radios.
4. 0620 hours – made up tow bridle to tug; stood out from pier.
5. Mooring lines securing TFB rafts to pier were thrown-off by divers in pairs starting with forward set. The tug took up slack as mods. were freed.
6. 0633 hours – last pair of mooring lines were thrown off. Tug took custody of TFB tow.
7. Personnel on pier recovered mooring lines and shackles, hand over hand. Divers secured from water, observed tow underway from small boat.
8. Diving boat went alongside pier and picked up each mooring line from where it was recovered from water. Finally, line handlers were taken aboard and proceeded after TFB under tow. Dive boat was underway 0648 hours.

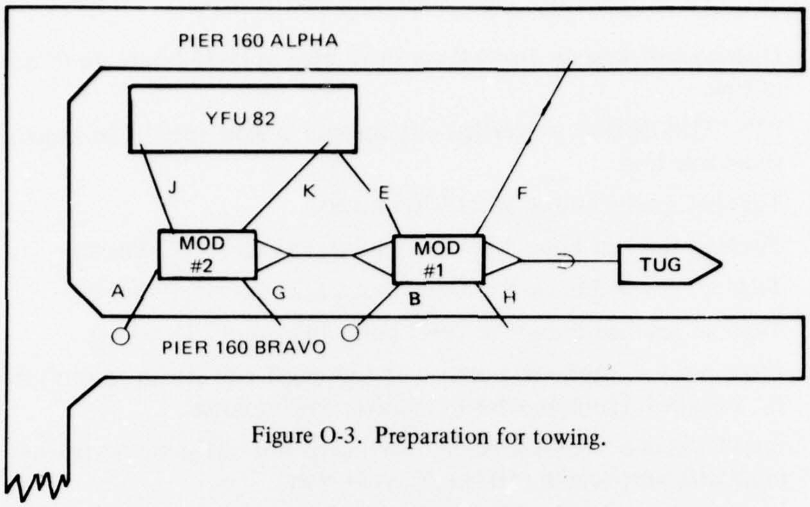

Figure O-3. Preparation for towing.

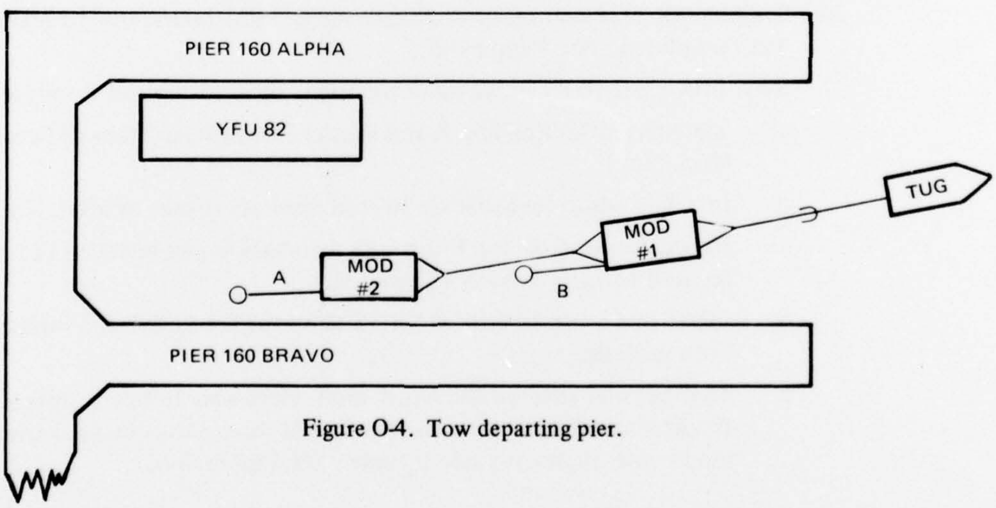

Figure O-4. Tow departing pier.

9. Dive boat picked up divers from small boat at 0655 hours; took workboat in tow.
10. PTS CORONADO proceeded out channel at slow speed 1200 turns P&S with short tow line.
11. Tugboat reached buoy 12 at 0705 hours.
12. Tugboat reached buoy 10 at 0738 hours (33 min = .92 knots).
13. Tugboat reached buoy 8 at 0800 hours (22 min = 1.39 knots).
14. Tugboat reached buoy 6 at 0842 hours (42 min = .72 knots).
15. From buoy 6, tug took a course of 135 deg T and streamed out towline to 350 ft. Installed dynomometer to monitor towing force.
16. Speed was checked by clocking passing of flotsam along 64-ft length of tow craft with stop watch (*ft/sec X .5921 = kt).
    a. 1500 RPM 20 sec 1.89 kt – average 4500 lb on dyno.
    b. 1750 RPM 15 sec 2.53 kt – average 5500 lb on dyno.
    c. 1900 RPM 12 sec 3.16 kt – average 7000 lb on dyno.
17. Tug captain set maximum speed of 1900 turns since propellers will cavitate with 2100 turns at less than 5 knots.
18. Installed additional thimbles in tag lines to convert for mooring line duty.
19. Arrived at the operation area staging buoy at 1120 hours. Divers embarked in workboat to pick up buoyed trailing line.
20. Trailing line was secured to staging moor at 1125 hours; tow to installation site was completed. See Figure O-5.
21. Start procedure to rig breakwater modules for mooring and flooding.
    a. Transferred trailing line B and shackle to starboard forward corner of Mod. No. 1.
    b. Installed additional shackle to starboard aft corner of Mod. No. 2.
    c. Passed free end of line B through the shackle just installed (21 b) and secured to surface buoy (12 in. dia.).
    d. Installed six pieces 4-in. dia X 15-ft buoyancy tank interconnect hoses on both modules.
    e. Tugboat maneuvered the No. 1 mod. clockwise to bring units side by side. Workboat maintained tension on line B throughout maneuvering to draw mods. into alignment side by side. See Figure O-6.

*Note: Module No. 1, which was launched from the assembly barge on the day prior to this installation was found to have an internal pressure less than ambient when the time came to install hoses. This condition was produced when the threaded caps were removed and regreased in preparation for launching, and were replaced on a warm day leaving ambient pressure in the ballast tanks. Cooling of the volume when launched plus submergence to a depth of 12 ft. more or less produced a negative differential pressure at the hose

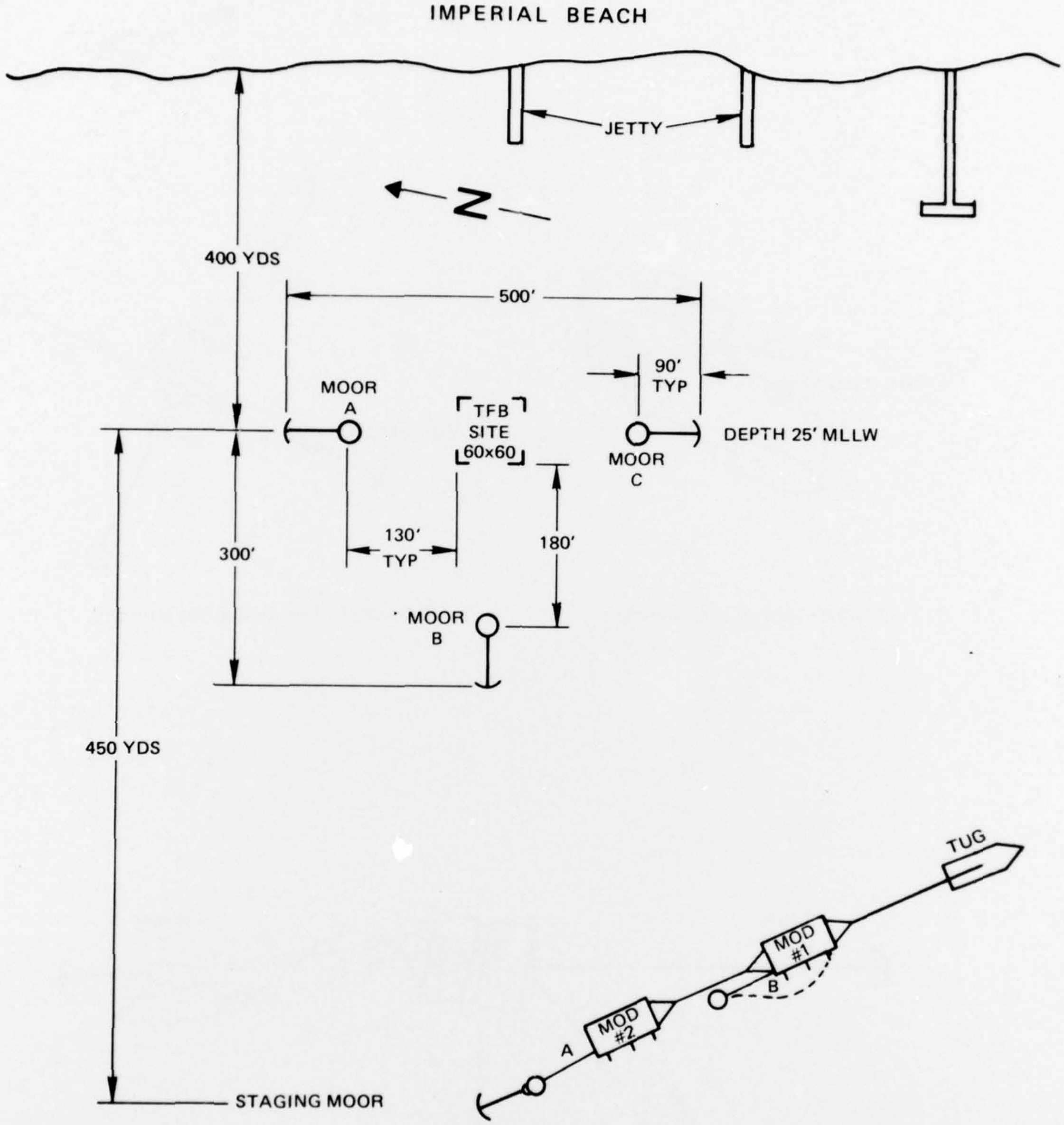

Figure O-5. Arrival at mooring site.

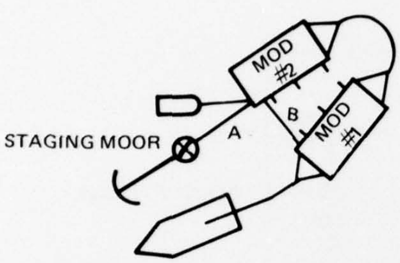

Figure O-6. Assembly of modules.

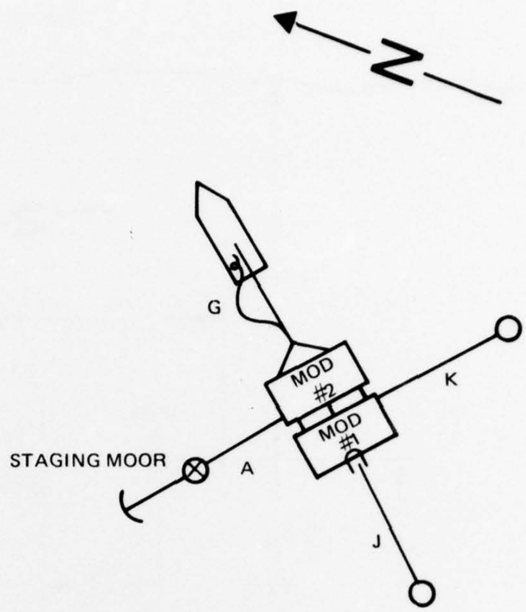

Figure O-7. Preparation for mooring.

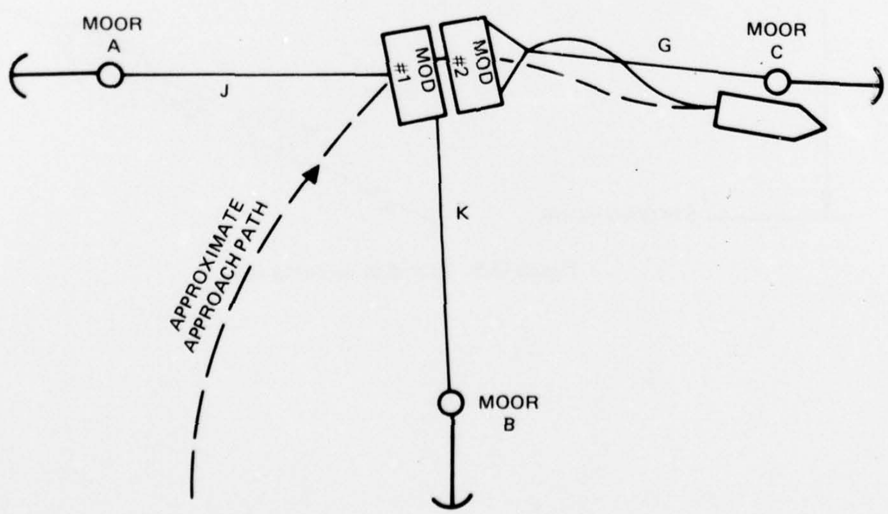

Figure O-8. Maneuvering into mooring position.

fitting. Divers were obliged to lever the protective caps from the fittings on the flood side of each of the three ballast tanks slated for a hose connection. The 5 to 6 PSI differential produced a substantial inrush of water when the cap was pried off. When the 4-in diameter hose was offered to the connection, exterior water pressure forced it home smartly. Divers reported the connection as appearing to be properly seated and locking levers were secured with normal feel. However, all three intertank hoses leaked profusely, resulting in the sinking of the raft assembly at a perceivable rate. The actual source of the leaks was determined to be distorted gaskets.

f. Installed 12-inch diameter yellow marker floats on the 2-in main vent valve of each assembly.

g. Divers shackled dangling interconnect chains (3 places) together as soon as modules were close enough. DANGER – Swimmers were required to exercise caution when working below the modules, being careful not to blunder between the structures – the possibility for severe injury existed.

h. Disconnected both ends of the inter-module tow bridle and passed to workboat. Retrieved bridle from water and stowed it aboard diving boat. Retained shackle on starboard quarter of Mod. No. 1.

i. Disconnected tow bridle from leading end of Mod No. 1 and passed entire bridle to workboat. Repositioned tugboat off port side of Mod. No. 2, stern-to. Assembled tow bridle with port side of Mod No. 2 and returned free end to tugboat. See Figure O-7.

j. Transferred mooring lines J, K and G to workboat. Installed line J on port side of Mod. No. 1, assembled with wire strap and shackle provided on ballast assembly. Attached a 12-in diameter yellow float to end of line and cast off. Installed line K to starboard aft corner of Mod. No. 1 using shackle left in place in h above. Installed 12-in yellow float and cast off. Installed line G to ring in tow bridle. Passed free end to deck of tow craft. Time at completion of this task was 1345 hours.

At this point the TFB breakwater was ready to be cast off from the staging moor and towed into position. However, the flooding situation described in the above note had, by this time, progressed to the point that the buoys were half-submerged, and the ballast flooded to the point of exposure on the high end – approximately 18 inches were above water. Therefore, assembly operations were suspended to conduct a deballast drill, which would expel the ballast water with compressed air provided by the low pressure compressor aboard the diving boat. The diving boat was secured at the bow by the A mooring line and hauled up close to the breakwater assembly. A hose coupling was installed in the ½" vent valve on the low end of the starboard (presumed heaviest) ballast tank, and the cap removed from the 2 inch standpipe of the same tank. Air from the diving boat compressor was admitted at maximum flow. The compressor was able to maintain 35-38 PSI in the 200-ft, l-in diameter delivery hose. Approximately 25 minutes passed before the first tank vented air from the standpipe.

The raft was nearly righted at this point showing that most of the flooding was in the starboard outside tank. The tank was capped, and then the standpipe cap removed from second starboard tank. This tank vented air in ten minutes. The compressor used for deballasting is rated at 70 SCFM at 200 PSIG, or 80 SCFM at 100 PSIG. As a wild guess the unit might deliver 100 CFM at 35 PSIG. After venting the second tank, the breakwater assembly was stable or level enough to secure deballasting and resume the mooring and controlled flooding sequences. It must be pointed out that substantial leakage was still occurring at the 4-in. diameter hose connections on the end of the hose with a female coupling. Ordinary operations resumed at 1435 hours.

k. Tugboat maneuvered to remove slack from towing bridle and relieved tension on the mooring line to the staging buoy.

l. Divers cast off mooring line from the module, disconnected line from mooring buoy and passed it to the workboat for recovery. Tugboat got underway at 1445 hours.

m. Tugboat maneuvered with breakwater in tow, to pass through center of mooring buoy triangle such that the trailing lines could be shackled to mooring buoy by workboat personnel. Connected line J to the north shoreward buoy, then connected line K as the raft came abreast. Finally, line G was passed to south mooring buoy holding the breakwater assembly in the proper location and attitude for bottom emplacement. See Figure O-8. Difficulties were encountered in execution of this mooring scheme, due to passing through the mooring buoy triangle on a turning course which passed closer to buoy B than to buoy A. Hence, the first connection at buoy A was not within reach, but no boat was available to connect line K as the close passing was made. As a result, much pulling and tugging was needed to connect line J to its buoy by the workboat while the diving boat fought vainly with K to maintain position at the central moor. An auxiliary line about 80-ft long was used to stop off line K to the buoy. The tow craft, with ample horsepower available, was easily able to attach the third mooring to C. Finally, to keep the breakwater assembly in the correct attitude the tow craft was directed to pick up line G and keep a good strain on the breakwater assembly and pull it against line J. By this device the breakwater was held in good position and angle within the moor and flooding was started at 1535 hours.

n. Flooding was done with the 4 ballast tanks joined in series with the 4-inch flood port on tank A, and a vent hose to the surface on tank D as described in the standard flooding plan. Twenty minutes of flooding were sufficient to sink the first mod. and have it firmly grounded on the bottom in approximately 28 feet of water. Tide at 1530 hours was approximately 2.5 ft.

o. At 1550 hours flooding of the second mod. was begun. At 1610 hours normal flooding of both units of the breakwater was complete.

p. Clean-up of underwater equipment was started after the flooding was complete, which involved the following:

   1. Removed towing bridle and released tugboat from the project. Returned the tow bridle to diving boat.

2. Removed mooring lines J, K and G and returned them to the diving boat.

3. Removed 4-inch interconnect hoses and the two 2-in vent hoses and returned them to the diving boat.

4. Installed a length of 1-in dia polypropylene line (buoyant) between the breakwater assembly and the seaward mooring buoy B. Hauled the line down as tightly as possible and secured to the bottom-resting chain of the moor. This line served as a "tattletale" between the breakwater assembly, and a fixed reference point on the ocean floor. If tide and storm influences prompt the breakwater to shift position, then tension change of this buoyant line will serve as a measurable indicator. This completed the task of installing the breakwater. The diving boat secured from the operating area at 1755 hours. Personnel returned to NOSC at 1930 hours.

APPENDIX P
RELOCATION PROCEDURE
(90° Rotation)

1. Moor diving boat to seaward and northern buoy. See Figure P-1.
2. Install line A.
3. Install line B.
4. Remove one inch polypro line.
5. Install auxiliary 100-ft line with float on each module.
6. Attach four-inch diameter interconnect hoses to each ballast tank after removing dust caps and plugs. Open valves.
7. Install two-inch diameter vent hoses; buoy-off on surface.
8. Install tow bridle and pass it to tug.
9. Connect air hose from compressor to Module No. 2; deballast tanks in sequency starting with southernmost tank.
10. Transfer air hose to Module No. 1 and deballast.
11. Reposition dive boat.
12. Maneuver both assemblies when completely afloat. Rotate 90° so that ballast tanks are parallel to beach. See Figure P-2.
13. With breakwater in position, start flooding Module No. 1.
14. Flood Module No. 2.
15. Remove tow bridle; release tug.
16. Remove lines A and B; remove vent hoses and four-inch interconnect hoses; replace dust caps and plugs; close all valves; remove all miscellaneous shackles and auxiliary lines.
17. Make general inspection.

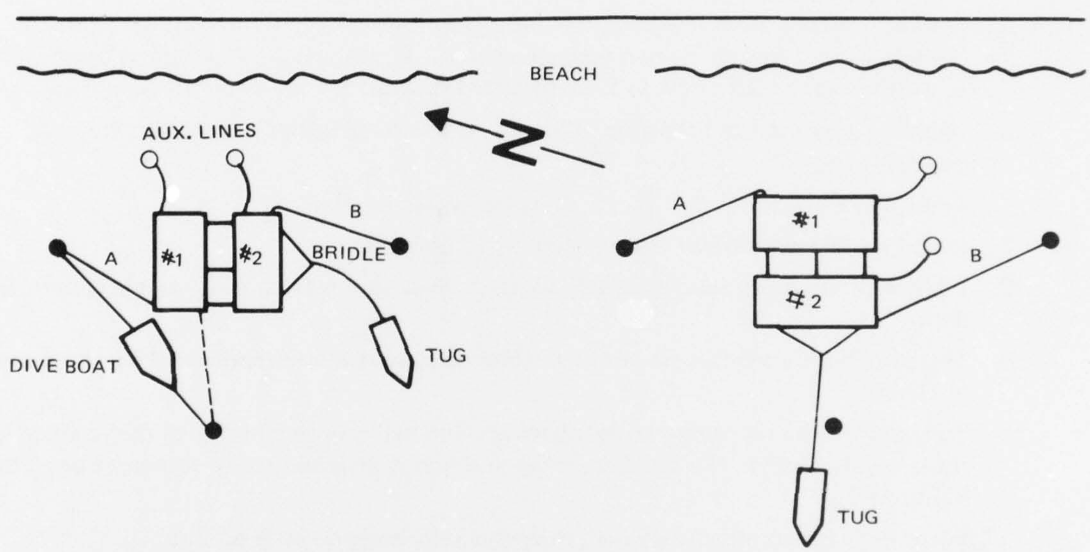

Figure P-1.

Figure P-2.

APPENDIX Q
RELOCATION PROCEDURE
(TRANSFER TO NEW TEST SITE)

1. Moor MIKE-8 boat between seaward and northern buoys. See Figure Q-1.
2. Install line A.
3. Remove dust caps and plugs from four inch diameter fittings. Install all interconnect hoses. Valves to remain closed.
4. Install tow bridle and pass to tug (PTS CORONADO) to keep a strain.
5. Connect air hose from low-pressure compressor on MIKE boat to outboard tank on Module No. 2. Attach via two-inch stand pipe. Remove stand pipe cap at opposite end to vent the tank. All tanks to be deballasted separately for greater attitude control.
6. Deballast tanks in the following order: A, D (outboard); B, C (inboard). Replace standpipe caps.
7. Transfer air line to Module No. 1; deballast in same order.
8. Install line B with surface float attached (12 inch dia).
9. When both modules are completely afloat, release line A from moor and attach surface float.
10. Tug tows both units to new test site. (Modules are still inter-connected by three lengths of chain.)
11. Tug maneuvers breakwater to pass between the two mooring buoys so that trailing line B can be attached to the northern buoy and line A attached to the leeward buoy. See Figure Q-2.
12. When in position, attach two-inch diameter vent hoses to each module.
13. Flood Module No. 1 by opening the four-inch valves, removing four-inch diameter pipe cap and then opening two-inch valve.
14. Flood Module No. 2 in the same manner.
15. Remove tow bridle and release tug.
16. Remove lines A and B; remove all vent hoses and four-inch interconnect hoses; replace dust caps and plugs; close all valves; replace four-inch pipe cap.
17. Make general inspection.

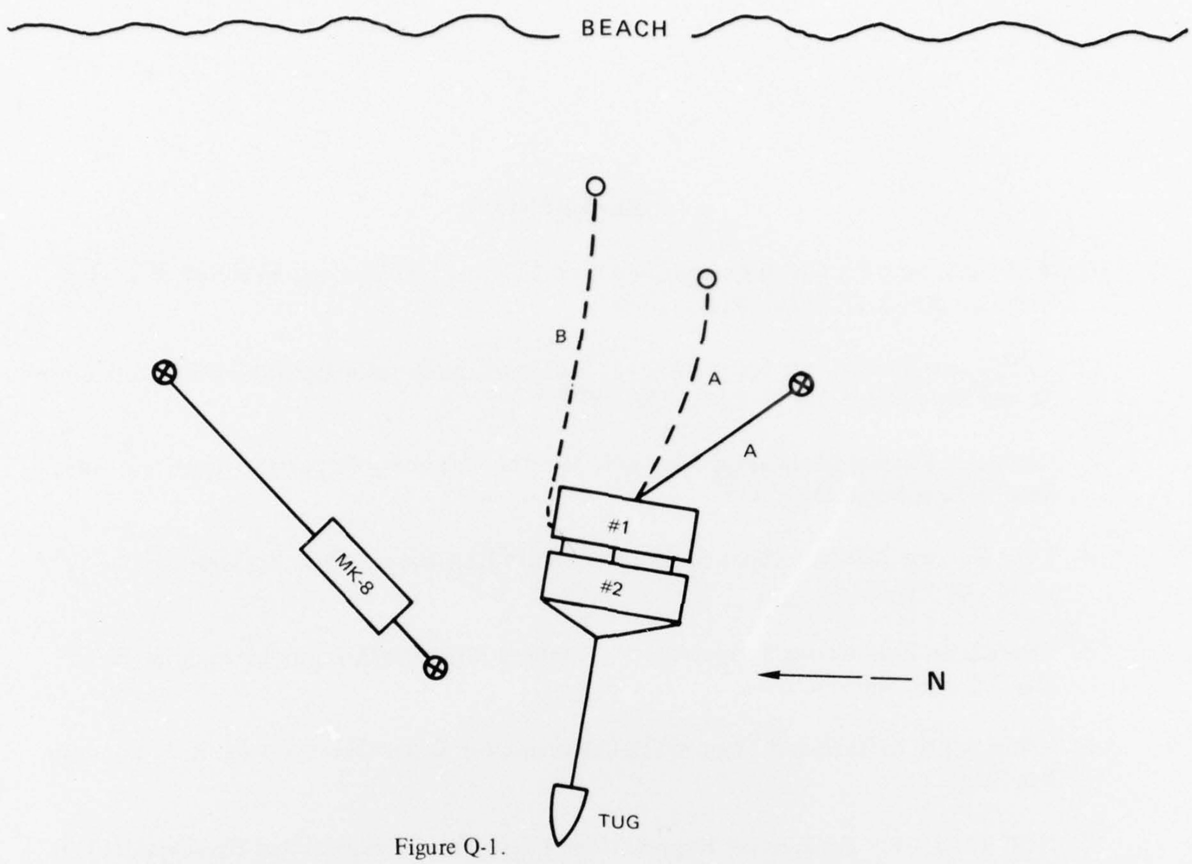

Figure Q-1.

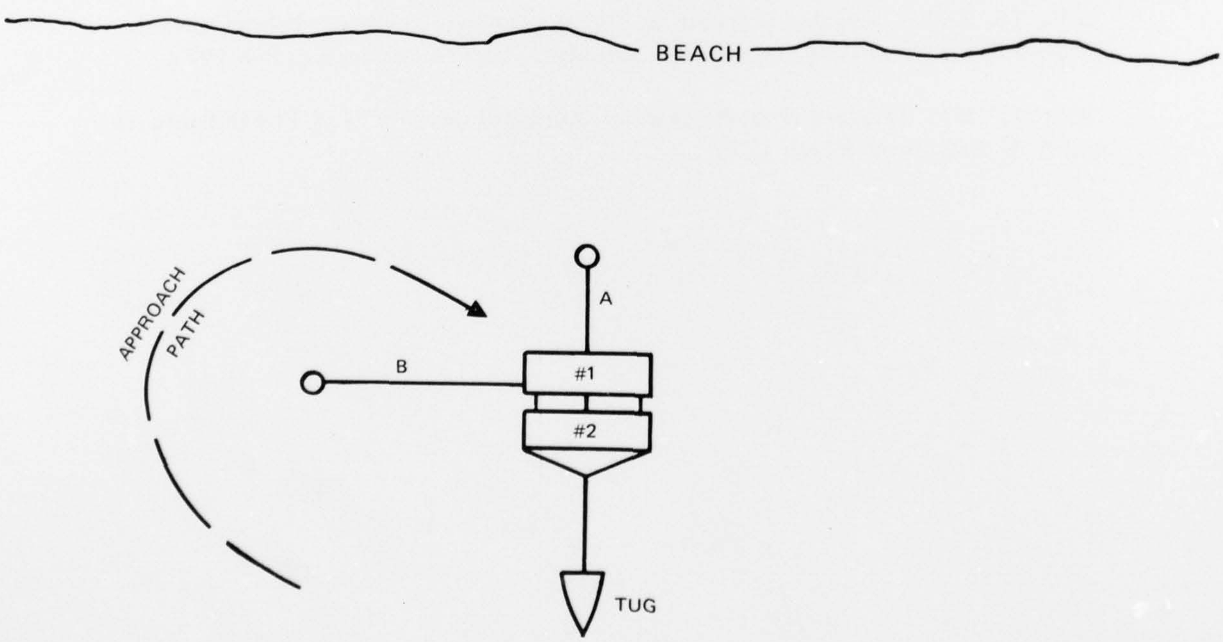

Figure Q-2.

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